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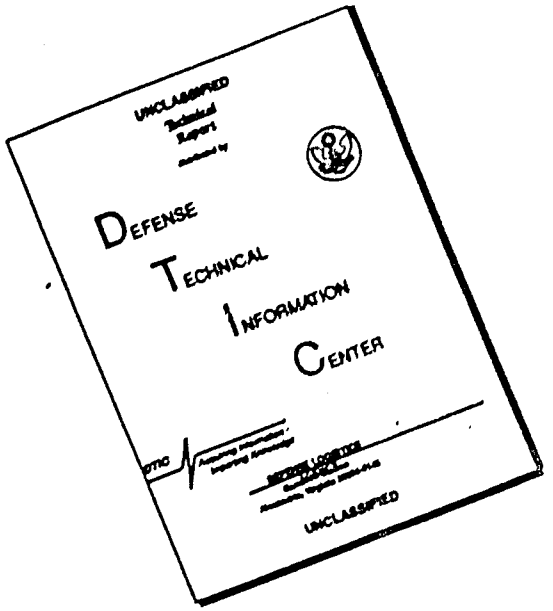

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April 1961

Explorations in the Measurement and Prediction of Contributions of One Sample of Scientists

By
Calvin W. Taylor,
William R. Smith, Brewster Ghiselin,
and Robert Ellison

University of Utah
Contract AF 41(657)-158

PERSONNEL LABORATORY
AERONAUTICAL SYSTEMS DIVISION
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
LACKLAND AIR FORCE BASE, TEXAS

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Project 7717, Task 17110
Contract AF 41(657)-158

Personnel Laboratory
AERONAUTICAL SYSTEMS DIVISION
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
Lackland Air Force Base, Texas

FOREWORD

This project was carried out under Contract AF 41(657)-158 with the University of Utah. During approximately the first year of the three-year term, the monitor for Personnel Laboratory was Dr. Robert M.W. Travers, now with the University of Utah; and for the remainder of the term, Dr. A. Carp, Technical Director, Personnel Laboratory. Dr. Calvin W. Taylor was the Principal Investigator. In addition to the four authors of this report, others who assisted in the project were:

John Woolayer	Keith Hansen
Gary Cooley	Frank Sessions
Joyce Eliason	Lorraine Loy
Madge Nickell	Mary Porter
Margery Kay	Willard Snow
Carolea Orton	James Ziegler
Elizabeth Smith	Robert Haygood
Jeane Ashton	Lois Goodwin
Doris Booker	J.M. Richards, Jr.

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ABSTRACT

Physical scientists at two Air Force research centers were intensively interviewed concerning the nature of scientific productivity and the characteristics of effective scientists. Based on these interview suggestions, data were collected on 52 criteria. These were reduced analytically to 14 factor scores. Following this, several tests and questionnaires were developed for tryout as predictors. Scores from these and previously developed instruments that showed promise were correlated with the factor scores and three of the original criteria. In the sample of 107 scientists, criteria most related to tests and questionnaires (in terms of number of significant correlations) were ratings of likableness as a member of a research team, membership in professional societies, organizational status, rated work output, supervisory ratings on overall performance, and peer rankings on overall productivity. The instruments that had scores correlating with the greatest number of criteria were a biographical data questionnaire, self-ratings, and a questionnaire designed to measure minimum level of aspiration. The outcomes of this investigation were identification of a wide variety of measurable criteria and a number of self-report instruments suitable for future longitudinal followup and validation as a means of identifying kinds of scientific talent needed by the Air Force.

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EXPLORATIONS IN THE MEASUREMENT AND PREDICTION OF CONTRIBUTIONS OF ONE SAMPLE OF SCIENTISTS[1]

The current demand for scientific progress in the nation has stimulated an increasing interest in the nature of scientific talent and its identification, development, and utilization. During the past few years, several researchers (Cattell, 1959; Mullins, 1960; Roe, 1958; Saunders, 1956; Stein, 1956; D.W. Taylor, 1958) have completed one or more exploratory studies on some aspect of scientific talent, especially pertaining to creativity and productivity in scientists. This report covers a three-year project designed to determine methods of predicting productivity and creativity in Air Force basic research laboratories. The work progressed in six phases: (a) exploration of the problem of measuring the extent to which scientists are making contributions to the various phases of the work in the Air Force research and development program to which they are expected to contribute; (b) development of methods of measuring or assessing the variables defined in the previous phase and collection of such criterion data; (c) exploration of methods for identifying important personal characteristics which differentiate between productive and nonproductive scientists; (d) development of tests and other devices to measure the variables hypothesized in the previous phase; (e) administration and analysis of the tests; and (f) selection of a battery of instruments which predict scientific productivity and provide a psychological model of the productive scientist.

Two major studies were to be accomplished in this project. The first one was to deal with the problem of creative, productive, and other contributions of scientists. The second study was to develop measures of psychological characteristics presumed to be important in science and to validate these measures against the criteria developed in the first study of the project. A large interviewing activity preceded these two main studies. The interviews were designed to gather suggestions from a large sample of scientists on the various types of contributions of scientists and on the psychological characteristics that may be valid as predictors of one or more types of these contributions of scientists.

Relevant studies in the area, such as those by Charness (1955), Pelz (1955), and Stein (1957), were considered when constructing instruments for collecting the criterion data on scientists. These suggested criteria included possible ways for estimating a person's capacity for (a) fulfilling functions as a scientist, (b) fulfilling functions as an employee of an organization, (c) fulfilling functions as a member of a profession, (d) exercising leadership in research, and (e) promoting the ideas of others.

These studies and most other recent research studies on creativity and productivity of scientists have been reported and considered in the University of Utah series of research conferences on "The Identification of Creative Scientific Talent" (C.W. Taylor, 1956, 1958, and 1959). These conference reports have provided one of the main bases from which this large-scale research project on scientists in research laboratories has been undertaken.

Criteria of success in science have not been well understood because few comprehensive scientific investigations of criteria have been undertaken. Uncritical judgments might lead investigators into a consideration of publications, patents, or other obvious tangible products as the sole criteria of success, but after closely analyzing scientific productivity it appeared that other contributions are required of scientists that would also be called productive. The word "contributions" was chosen in this research project when referring to productive and creative

[1] Manuscript released by the authors for publication as an ASD Technical Report in January 1961.

acts since it is broader in connotation, including the fruitfulness of scientists in various roles and activities, and is better understood during communications with the scientists than either productivity or creativity.

From an intensive review of the related work the investigators found little information conclusive enough to justify adopting dogmatically any single criterion or group of criteria directly. The studies reviewed represented attempts to better understand the nature of the criteria of productivity and creativity in science, but at the same time were not definitive or comprehensive enough to satisfy all of the needs of the present study. An attempt was made in this research to identify and measure all of the possible criteria of success in science that might lend themselves to analysis in the experimental framework of the project.

The initial approach involved the conducting and analyzing of over 200 extensive interviews with scientists in two research centers.[2] Scientists' statements about criteria of contributions were analyzed and organized to yield a list of about 150 criterion scores which could be obtained from criterion instruments. Means for collecting data on these contributions in science were devised and complete criterion and predictor data were collected on the large majority of the scientists in one directorate at one basic research Air Force center.

This report will first present the intensive interviewing study and analysis, followed by the study of the multiple contributions of scientists. The prediction study, which was designed to identify psychological characteristics related to each type of contribution of scientists, will be reported last in the sequence.

THE INTERVIEW STUDY AND INTERVIEW ANALYSES

The interview study admittedly entailed very subjective approaches, which nonetheless helped considerably in the design of the methodology for criterion data collection. Three members of the staff interviewed over 200 physical scientists at two basic research centers. The interview information was kept anonymous to protect those interviewed and to encourage frank opinions from the scientists. The interviews were nonstructured, informal discussions which generally focused on the nature of scientific contributions in the laboratories where the study was being conducted, the kinds of effective scientists one might find in such laboratories, personal background information, and other topics brought into the discussion by the scientists, such as comments about their working conditions. The average length of the interviews was two hours. Most of the interviews pursued the following issues: (a) types of scientists, (b) kinds of work done, (c) personal background information, (d) probable criteria of scientific productivity and creativity, (e) suggested ways for recording and scoring behavior on such criteria, (f) nature of the talent in one's own laboratory, (g) ways of predicting success in science, (h) conditions which influence scientific contributions, and (i) other questions which seemed appropriate in each interview situation.

At first the interviews were tape recorded, but the method had so many negative features that it was decided to merely abstract the interviews in written form while the scientist and interviewer were talking. Many scientists objected to having their comments appear on tape and they stated that they did not feel free to express their true opinions while the tape recorder was running. Also, the available recorder was cumbersome to transport to the widely scattered offices and interfered with the smooth flow of interview information.

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[2] These interviews were conducted mainly by William R. Smith.

While being interviewed, each scientist was asked to discuss freely any ideas he wished which were related to productivity and creativity in research, e.g., possible criteria of success in science and possible predictor tests. This task resulted in many statements which implied that working conditions have important effects on the quantity and quality of scientists' contributions as well as statements related to the primary goals of the project.

Information about the effects of different working conditions on the quantity and quality of scientists' contributions is needed before maximum utilization of scientific talent can truly be achieved. The obvious assumption underlying such a statement is that certain factors found in the working environments of scientists affect, either favorably or unfavorably, certain aspects of their professional performance.

An analysis of the interview statements suggested the following kinds of criteria:

1. Ratings by others of the scientist and of his scientific products. Typical of such criteria were subjective ratings of productivity by one's supervisors, peers, and a research psychologist; a complex quality and quantity evaluation of publications and research reports; and the collection of quality and quantity information about patents and invention disclosures.

2. Collection of objective facts about each scientist from Air Force records. The number of publications one had produced during a given two-year period with the organization; the number of patents, invention disclosures, and evaluations of them; number of contracts monitored; and organizational background history of each scientist were the major kinds of probable criterion information available from these records.

This interview information was utilized quite fully in the criterion study. Likewise all the suggestions in the interviews about characteristics of effective scientists were considered in planning the validation study.

THE CRITERION STUDY ON THE MULTIPLE CONTRIBUTIONS OF SCIENTISTS

The interviews had been conducted on samples of scientists at two Air Force research centers. The criterion data were collected on a sample of 215 physical scientists working in 15 different laboratories at one of these centers. Criteria were collected on 17 instruments yielding a potential 150 scores. These criteria were collected from supervisors, laboratory chiefs, peers, official records, reports and publications, and from the scientists themselves (on their society membership, etc.). An attempt was made to collect criterion data on all of the dimensions thought to be important as a result of the interviews. Some necessary control data such as age, years of experience, education, as well as some predictive self-ratings, were also collected on this sample. The subjective ratings of the scientists and their products were extremely time consuming, and the raters were so busy that individual time allowances had to be made in each case. Some scientists were reluctant to make any written record of their own judgments of fellow scientists. In other words, various difficulties were encountered in getting all of the criterion forms filled out. This made it impossible to collect the data in a short period of time. In some cases, negative attitudes of certain scientists in the sample had to be overcome by intensive explanations of the ultimate use of the data, or by changing the methods of data collection to fit their specific demands. One member of the staff remained on the scene during the eight-month period of the data collection to insure that maximum return of the data would be obtained.

During the data collection phase of the project the field research psychologist continually received feedback from the scientists about the ways to score the criterion data, together with further information on the nature of scientific productivity and creativity.

Several members of the initial sample were found to lack a number of the criterion scores, and 49 scientists were eliminated from the sample prior to the data analysis because of insufficient data. Those who had only a few criterion scores missing were retained in the sample by using an estimated score for each of the missing criterion scores. In several instances, the mean of the group was used for the estimated score, but occasionally the estimated score was determined from regression results found in small pilot studies and by using an estimated score based upon the results on the variable that was most like the missing one. Though this procedure was rather arbitrary and subjective, it allowed a relatively large sample to be studied by estimating a few scores on these difficult-to-obtain criteria.

The characteristics of the sample as to major discipline and grade were as follows. By discipline, 35% were physicists; 7% mathematicians; 48% electronic engineers; and 10% chemists. By civilian or military grade, 2%, were GS 7; 11% GS 9; 18% GS 11; 22% GS 12; 26% GS 13; 13% GS 14; 4% GS 15; 2% 2nd lieutenant; and 2% 1st lieutenant.

ANALYSES OF THE CONTRIBUTIONS OF SCIENTISTS[3]

The 150 scores originally proposed were reduced to 52 criterion scores for this first study. This reduction in scores was accomplished as a result of several small pilot studies on the data which led to combinations of highly related scores and elimination of some of the potential scores for reasons that seemed justifiable. For example, supervisory ratings on 17 characteristics were reduced, through combining scores, to 10 ratings. The 52 scores included 11 ratings and rankings by immediate supervisors; 4 ratings from higher level supervisors, the laboratory chiefs; 6 ratings, rankings, and nominations by peers; 9 scores taken from official records; 12 quantity and quality scores on research reports and publications; 1 score on membership in professional societies; 4 ratings from the researchers who worked on this project; and 5 control variables. These control variables (such as age, years of experience) were variables which were not directly concerned with contributions, as such, but which might account for some of the differences in contributions among scientists. If a sizable relationship were found to exist between any control variable and a particular contribution score, it would be necessary to partial out the effects of the control variable in the contribution score. The titles of each of these 52 scores with the source from which each one was obtained and the means and the standard deviations are listed in Table 2, Appendix A. The correlations among these scores are presented in Table 3, Appendix A.

Eight different sources were used for obtaining data about the contributions of the sample of 166 scientists in one large research laboratory. A first correlational analysis of the relationships among these contribution scores was made in terms of the different sources of information from which these scores were obtained. Scores from supervisors usually had a low positive correlation with those obtained from peers. Little relationship was found between the scores obtained from peers and those from laboratory chiefs. The relations between subjectively-obtained scores and scores obtained from records were generally negligible. Scores either from supervisors or from peers generally were unrelated to scores on research reports and publications, although there were a few exceptions. The five control variables were age, number of years of education, total number of years experience, length of experience at this particular laboratory, and a score on freedom from publication hindrances. These five control variables were generally

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[3] For further details about these various analyses, including the factor analysis, see C.W. Taylor (1959, pp. 5-18).

quite independent from the contribution scores. This is a noteworthy finding, since it was not necessary in this study to partial out the effects of any of these five variables on any of the contributions scores of the scientists. For example, the control variable of total number of years of experience accounted for little or none of the individual differences in contributions of these scientists. However, it should be mentioned that the effect of these control variables had already been largely cancelled out in a few contributions scores, such as patent rate and promotion rate (Table 2, items 28, 30). Nonetheless, it is interesting to find that the creative and productive contributions typically did not vary with either the age or the number of years of education of this sample of scientists.

One general conclusion drawn from this first analysis is that the data on contributions of scientists tend to be independent (much more often than not) when obtained from different sources. The second overall observation is that although the typical relationship across different sources of information is either low or negligible, a wide range of relationships was often found between different pairs of scores from any two sources of information. This latter finding suggests that a better basis for clustering or categorizing these contribution scores should be sought. Admittedly, however, the source of information does account for some of the variability found in these contribution scores, so that it represents an important aspect in the total problem of analyzing the contributions of scientists.

Another approach for viewing the relationships among the contribution scores was to find the number of other scores to which each one was significantly related. At one extreme, it was found that one score of contributions was related to only a single other contribution score; whereas at the other extreme certain contribution scores were related to about half of the other scores. On the average, a contribution score was related to only 20% of the other scores. This finding does illustrate the complexity of the total set of contributions, since, on the average, four out of five other contribution scores are independent of any given contribution score.

THE MAIN CATEGORIES OF THE CONTRIBUTIONS OF SCIENTISTS

The next method used to process the data was the factor analysis technique, as developed by Thurstone. In the factor analysis of the correlation table with its 1326 correlations, 27 factors were extracted before the level recommended by Tucker to stop extracting factors had been reached. A rotational solution using Thurstone's analytical method (1953) has been finished on the computer, based upon the 19 most significant factors, although only 15 categories (criterion and control factors) were interpreted and retained for use in the validation study. The unrotated factor matrix and the transformation matrix have been included as Tables 4 and 5 in Appendix A.[4] In effect, the number of main categories (factors or dimensions) of contributions was determined from the relationships and clustering of the contribution scores. Each score of the contribution of scientists was found to fall significantly into one or more categories to which the evidence showed it belonged. This technique of determining the main categories and of classifying each contribution score into its appropriate category or categories was accomplished entirely on a computing machine. These main categories proved to be largely unrelated to each other and thus formed a set of 15 relatively independent categories into which the contribution scores were classified. The results show that the source of criterion information is certainly not the sole basis of difference among these factors and that the 15 categories provide a clear and sound basis for organizing the correlational results among the criterion scores.

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[4] A second-order factor study among the primary factors of the first-order study has been partly completed, as a result of a suggestion from a leading factor analyst who hoped that greater simplicity in the total criterion problem would be found in the second-order solution.

The complexity of the total problem is again indicated first by the large number of different categories (15) required for adequately categorizing the 52 contribution scores; and second, by no more than 13 scores sorting into any single category, with the median number of scores per factor about six out of a possible 52. The machine solution indicated that two particular scores, number supervised and the productivity ranking made by the supervisor, were classified into a maximum (in this problem) of four out of 15 categories, 6 scores fell into three categories each, 20 scores were classified into two categories each, and the remaining 24 scores each fell into only one of the 15 different categories. This sorting of the various contributions of scientists into several main categories provides a powerful and interesting analytical view of the total problem under investigation.

The 15 categories of contributions have been arranged according to whether they represent science-oriented or organizationally-oriented behaviors. The first categories tend to be science oriented whereas the last ones (except for the control score category) are more organizationally oriented. A few categories in the middle of the listing are ambiguous and are not easily classified clearly into one of these two broad types. The appearance of scores with negative weights in some of these categories invariably proves to be an interesting and provocative phenomenon. Table 1 lists each contribution score as it was classified into each category, together with its weight in that category. This is the rotated factor matrix with rows rearranged and with all loadings be / .20 omitted in order to display the factor pattern.

Brief descriptions of the 15 relatively separate categories are presented below, with some mention of the contribution scores that fell into each category. The scores are usually presented so that the ones with greatest weight in the category appear first in the description.

Category A. This category represents *productivity in written scientific work.* A good measure of this category would identify scientists who are effective paper workers in the preparation of written articles, reports, technical memos, patent applications, and other scientific papers. Such persons are less frustrated than the average scientific worker in terms of the amount of their scientific work which is completed except for the final write-up. However, perhaps from their scientific orientation involving their dedication to completing their scientific contributions through the final write-up stage, they are more frustrating to their supervisors who rate them low on cooperation. The other two scores with smaller weights in this category indicate that the predictions about future productivity are above average for these productive paper workers and that these persons have more educational background in sheer number of years than do the typical research workers in this organization.

Category B. This category seems to be somewhat complex and puzzling. It may indicate the degree to which a scientist *has recently produced a quantity of research reports* in the organization, though it was not particularly related to total productivity. A scientist high in this category estimates that he will continue to be productive in publishing, has fewer than average complaints about hindrances to publishing, and is rated slightly above average on drive, resourcefulness, and persistence. He is also likely to engage in monitoring work. This last result does not seem to fit unless he was rewarded (if this is truly a reward) for his production of research reports by being given more monitoring work or unless he somehow got credit for research reports due to his monitoring role.

Category C. In general, this category includes all of the *quality* ratings *of research reports except for* the *originality* rating. The originality rating was the most different of the five ratings of research reports, correlating zero with the rating on elegance. Therefore this category contains the judgment by experts in his field of the quality of a scientist's research reports, wherein some elements of significance, but not of novelty, are included in the concept of quality.

TABLE 1. Factor Analysis of Contributions of One Sample of Scientists

Score Nr	Contribution Score[a]	Categories (or Factors)														Nr of Significant Loadings
		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	
37	Articles	58							-26	22							3
38	Reports, memos	37															1
10	Cooperotion	-36							64								2
28	Potent rote	29			21		24										3
17	Prod. predicted	27								40							2
50	Educ. yrs.	27				23											2
41	Write up incompl.	-26															1
40	Popers completed	21															1
22	Reports – 2 yrs		62												23		2
42	Pub. est.		23														1
29	Monitor		22				23								59		3
2	Drive, resource		21						63								2
43	Free-pub. bind.		21								-30						2
9	Persistence		20						60								2
25	Orgon. reports			70													1
24	Relev., reports			62													1
27	Eleg., reports			54													1
23	Signif., reports			42	51												2
4	Integrity			23					48								2
26	Orig., reports				72							-21					2
31	Suggestions				21								-24				2
36	Societies					53											1
35	Activities					22											1
34	No. supervised					21					34	40		24			4
52	Months in center					-20					23					48	3
16	Prod. rnk. peer						61			29							2
1	Prod. rnk. super.						58		20	29					25		4
45	Consultont						39										1
47	Lab. nomin.						35			20	49						3
44	New problems						27		23								2
12	50% retention						23			51							2
3	Moth, cogn., etc.						20		54								2
15	Sci. chor. cklist							84									1
14	Creot. cklist							79									1
13	Prod. cklist							66		20							2
8	Flexibility								67								1
6	Indep. discovery								65								1
5	Desire for facts								54								1
11	Creotion								51								1
7	Inform. obility								50								1
19	Likobility									39							1
46	Trustworthy									-22							1
48	Center nomin.									20	67	21					3
39	Popers read										34	38					2
21	Awords										25	54					2
20	Noncomply, olter.										-20						1
30	Promotion rote												54			-23	2
51	Work yeors												-23			80	2
32	Poy													89			1
33	Primory octivity													81			1
18	Proj. coop.														-28		1
49	Age															82	1

Note. – Decimal points are omitted.

[a] See Appendix A, Table 2, for complete names.

Category D. This category represents *originality of work and thought.* Such original thought apparently is carried through to the stage where it appears in the scientist's research reports judged by experts in his field to be original and significant, in patents, and in suggestions submitted and officially accepted in the organization. However, organizational awards and the creativity ratings made by the supervisor and by the laboratory chief did not fall into this category. Perhaps this category is really limited to originality in one's written products. It is interesting to find that originality is quite a separate characteristic of research reports as distinct from high quality ratings of elegance and organization of these reports.

Category E. The number and importance of scientific and professional *societies to which a person belongs* is the main feature of this category. Apparently those who have more education, who work at higher level activities in the research organization, and who supervise more people are qualified to belong to more societies. They have a higher self-rating on cognitive abilities, but are not the workers with higher seniority at this research organization.

Category F. The common feature appears to be a *judgment of actual work output* or *productivity* of the scientist as seen by those who work near him. These judgments in the form of rankings, nominations, or checklist ratings, are made by the peers in his immediate laboratory, by his immediate supervisor, and by the chief over his laboratory. It is note-worthy that the two highest weighted scores in this category are the productivity ranking by peers and the productivity ranking by immediate supervisors. The only non-judgmental score in this category was the patent rate score. Only one of the supervisor's ratings on the ten rating scales appeared with a significant weight even though the supervisor's productivity ranking of the scientists was the next-to-highest weighted score in this category.

Category G. The three scores in this category were all obtained from laboratory chiefs. They clustered together more highly than any other set of contribution scores in the study and all three were derived from successive sections of checklist items that appeared on the checklist form in the study. On this form the first two checklists on *creativity and productivity* were those developed and used by D.W. Taylor (1958), pp. 36-43). The third checklist of creative characteristics of scientists clustered closely, although it was scored by merely adding the number of checks instead of applying predetermined scale values to each item checked. This category might be judged to represent the view of each scientist as seen from certain higher levels in the organization.

Category H. This category appears to be the *supervisor's overall evaluation* of the scientist based on all characteristics of his job, as represented in the 10 rating-scale scores used in this study. The supervisor's ranking of the scientists on productivity was barely classified into this category. Nominations by peers of the person to whom they would most prefer to assign a new problem also appeared with a low positive weight. The number of journal articles of the scientist had a low but significant negative weight. This negative weight may again be indicative and supportive of the conflicts that a scientist may face as he tries, on the one hand, to satisfy the supervisory organization and, on the other hand, to complete his contribution to his scientific field by publishing articles on his research work.

Category I. This category is interpreted as *likableness* as a worker in the organization. The scores with the highest weights indicate, at least indirectly, how well various persons like to work with him and to what degree they would like to keep him as a fellow worker. These judgmental scores come from the chiefs, supervisors, peers, and the project researcher who interviewed intensively most of the sample and also worked with them in the collection of the

contribution scores. It is interesting that the number of journal articles appears in this category. However, the nomination by peers of persons whose word in their technical field can be highly trusted has some component within it that is negatively related to this likableness characteristic – this negative component may indicate a below average chance of scientists so nominated being retained if layoffs were to occur.

Category J. The most common thread present in this category is the *visibility* of the person or of his name throughout the organization – in other words, how well known is he in person or by name in the entire organization. He tends to be nominated as an outstanding scientist by persons outside of his own immediate laboratory; he supervises more persons than the average; he appears in public and in the news by presenting papers (but not necessarily publishing them); he has worked longer with the organization; and he has somehow managed to win a few more awards, on the average. Being so visible and outwardly active in supervising and in presenting papers, he had more than an average number of complaints about publishing difficulties, but was slightly more cooperative and compliant in fulfilling the demands of this project than was the typical scientist.

Category K. The highest weighted score in this category is the number of official awards received in the organization, a form of *organizational recognition* for one's contributions in the organization. Perhaps the category really involves social recognition for one's visible type of contributions in working with people and in being an effective oral communicator. The basis on which awards are actually granted may well deserve closer study since the awards score is related to the number supervised (do organizational awards mainly go to supervisors?) and to the number of papers read, another visibility index. The real challenge that emerges in this category is that the number of organizational awards is slightly negatively related to the rating of originality of the scientists' research reports.

Category L. This category may represent the degree to which each scientist has *status-seeking, "organizational-man" tendencies.* The promotion-rate index is the score that appeared most prominently in this category. Most interestingly, this analysis shows that those who make official suggestions to the organization and who rate themselves as being high in the desire to discover new principles in science have a below-average rate of promotion. One possible explanation is that those with a slower promotion rate tend to rationalize by claiming that they have an above average desire to discover in science. An alternate explanation is that some research organizations may tend to promote those who do *not* make official suggestions as well as those without a strong desire to discover (but possibly with a strong desire for promotion and status). Further evidence relevant to these and other possible explanations is presented later in the validation results for this category.

Category M. This category seems to involve the *current organizational status* of each worker in the sample. His official status in the organization (which is consistent with the typical American view of status) is indicated by his rate of pay, the index of the level of his primary activity, and the number of workers he supervises.

Category N. The most prominent score in this category is the *contract monitoring load* of each scientist. Apparently those who are ranked high on productivity by their supervisor and who recently produced a large number of research reports within the organization tend to have an above average load of monitoring research contracts with outside contractors. The persons with heavy contract monitoring loads usually had some responsibilities for inside research work, so that they were extremely busy people and were rated by our project researchers as being below average in their cooperation on our research project.

Category O. This category, which includes three control scores, seems to measure predominantly the *total years of work experience* of each worker. Age is highly related to years of work experience, and the amount of time worked ct this research organization is a part of the total time a scientist has worked at all organizations. The only other score in this category was promotion rate, with a small negative weight.

The other main control scores of years of education and freedom from publication hindrances did not appecr in this category. In fact, the number of years of education appeared only in Category A involving the ability to do effective paper work and in Category E involving scientific and professional society membership.

Six of the above 15 categories contained at least one score that might be called a creativity score. For example, Categories A and F are complex and include patent rate within them; Category D involves originality in written work; Category G includes a creativity rating by the laboratory chief; Category H includes a supervisory rating on creativity as well as on flexibility and independence; and Category K may entail some form of creativity in administrative work since the score on organizational awards appears most strongly in it.

Initially we were somewhat puzzled about finding such great complexity in the total contribution area, as indicated by the many low intercorrelations (low overlap) and thus the high specificity in these measures on contributions. As time has elapsed, however, we are getting indications from other studies that this finding of relatively great complexity is quite sound.

Admittedly this study has involved analysis, but not synthesis. No attempt has been made to estimate the total contribution of a scientist by combining in some best-weighted fashion his contributions in each of the above relatively separate categories. Thus no value judgment has been made about the relative importance of each of these categories, though any organization could make such judgments in terms of its particular overall goals.

THE VALIDATION STUDY TO IDENTIFY CHARACTERISTICS OF SCIENTISTS RELATED TO EACH TYPE OF CONTRIBUTION

THE CRITERIA AND CONTROL SCORES

The second major study required in the project was to determine each set of psychological characteristics related to each of the different categories of contributions of scientists. In effect, there were 17 different targets (criterion or category scores of contributions of scientists) used in this second study. A variety of psychological tests yielding a large number of scores were correlated with each of these 17 criterion scores to identify the characteristics that correlated significantly with each type of contribution in science.

The 14 categories for which criterion scores were computed (numbered 1 to 14 in this validation study) are listed below. The score for each criterion category was obtained by a best-weighted combination of the set of original criterion scores with the highest loadings in that category. The weights were obtained by means of a multiple correlational analysis against the total factor score for each criterion. (See Table 6 in Appendix A.) Three original scores were retained as separate criterion scores 15, 16, and 17, since they represent typical criteria used in studies on the job. These were a peer ranking on overall productivity, a combined supervisory rating on drive and resourcefulness, and a supervisory rating on creativity. Table 7, Appendix A, presents the intercorrelations, means, and standard deviations for the 17 criterion scores.

The last category in the criterion study contained the three main control scores: age, total years of work experience, and total months of work experience at this research center. These three control scores, though highly related, were retained as three separate control scores, numbered 18, 19, and 20 in the validation study.

Another control score, years of education, was found in the criterion study to be related to only two categories, with a loading of .27 in the category of productivity in written scientific work (effectiveness as a paper worker) and .23 in the category of scientific and professional society membership (for which there may be educational prerequisites). Since years of education can be alternately considered to be a predictor score as used in many selection programs and since its validities had been determined and were found to be essentially zero for 12 of the 14 criterion factors, it was omitted as a score in the validation study.[5]

SEVENTEEN MEASURES OF CONTRIBUTIONS OF SCIENTISTS

1. Productivity in written work (effectiveness in completing paper work).
2. Recent quantity of research reports (number of articles, research reports, etc., in a two-year period).
3. Quality (without originality) of research reports.
4. Originality of written work.
5. Scientific and professional society membership.
6. Actual quantity of work output as judged by peers, supervisors, and laboratory chiefs (higher level supervisors)
7. Creativity rating by laboratory chiefs (higher level supervisors).
8. Overall performance (quality ratings by supervisors on 10 scales).
9. Likableness as an effective member of the research group.
10. Visibility of the scientist (well known by person or by name).
11. Recognition for organizational contributions (organizational awards).
12. Status-seeking, "organizational-man" tendencies.
13. Current organizational status.
14. Contract monitoring load.
15. Peer ranking on productivity as a scientist.
16. Supervisory rating of drive-resourcefulness.
17. Supervisory rating of creativity.

THREE CONTROL SCORES

18. Age.
19. Total years of work experience.
20. Total months of work experience in the research center studied.

The question on these three control scores is whether age, total work experience, and total experience in this research setting are related to any of the above 17 contributions or to any of the psychological characteristics leading to the above contributions.

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[5] An additional factor emerged primarily among the self-ratings in the first study. Although self-ratings had been available early and four self-rating scores had been included, perhaps prematurely, in the criterion study, these self-ratings were considered to be predictors rather than criterion scores; so they were generally not reported in the criterion study and were included separately among the predictor scores in the validation study.

SELECTION AND DEVELOPMENT OF PSYCHOLOGICAL TEST SCORES

The problem of the selection ond development of tests was especially difficult because of the numerous possibilities to consider. The reseorch team decided to use promising scores from intellectual, self-rating, personality, motivotional, and biographical tests; so o variety of tests of each type were considered for inclusion. Multiple scores per test were favored wherever they were promising ond possible, ond no limitation of using only existing tests was imposed.

Suggestions for tests or test ideos were found from the interviews of the scientists, from intensive studies of the three Utah creativity conference reports (which yielded mony more than one hundred suggestions including several with some supportive evidence from smoller studies), from basic reseorch on intellectual and nonintellectuol chorocteristics, including research on communication abilities (C.W. Taylor *et al.*, 1958) and from other readings and research experiences of the investigators. Toble 8, Appendix A, gives the list of names ond numbers of the 130 scores to be volidoted os predictors.

Direct self-ratings on 17 charocteristics suggested by the scientists were collected on speciolly constructed seporate roting sheets during the first criterion-study field trip. These 17 characteristics were drive, mathematicol ability, resourcefulness, cognition, integrity, desire-for-focts, desire-for-principles, desire-for-discovery, informative obility, skill in design, flexibility, persistence, independence, discrimination of value, cooperotion, intuition, ond creativity.

After considerotion of several competing devices, the personolity test chosen wos the Personolity Research Inventory, recently developed by Saunders (1955) in his personality reseorch program at Educational Testing Service, which yielded 26 scores with verbol descriptions similar to those felt to be important in creotive scientists. The 26 PRI scores were self-insight, free-floating anxiety, self-acceptance, tolerotion of frustration, toleration of ambiguity or complexity, compulsiveness, impulsiveness, altruism, tolkativeness, self-sufficiency, gregoriousness, oggressiveness, attitude to work, foresight, belief in right of individuals, belief in rights of groups, sociol conscience, stotus aspirotion, social know-how, social status, masculine vigor, artistic vs. practical, spiritual vs. material, progressive vs. conservotive, liking to think, ond PRI acquiescence.

More than 40 intellectuol tests were studied after being judged to have potential volidity. Seven short and factoriolly different intellectual tests, most of which hod multiple scores, were finally chosen, including two on asking questions and on suggesting improvements, both of which seemed to have some motivational ospects. The tests were Match Problems (Adaptive Flexibility factor) with three scores on correct responses, wrong attempts, and per cent correct; Consequences (Originality and Broadly Diffused Attention foctors) with two scores on total acceptoble responses and remote responses; Revision II (C.W. Toylor *et al.*, 1958), the most frequently valid predictor in the communicotion abilities project, with three scores on ideas, words, and rotio of words per idea; Visuol Imagery[6] (probably Visuolization factor) with three scores on correct responses, wrong attempts plus skips, ond per cent correctly morked; Word Association (Associational Fluency factor) with three scores on total words, totol close synonyms, ond number of sets; Pertinent Questions (Conceptuol Foresight Foctor) with only one score, the number of suitoble responses; and Apparatus Test (Sensitivity to Problems factor) with only one score, the number of suggested improvements.[7] The last two tests were selected because these were intellectuol tests that were motivotionol in nature.

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[6] Revised from a test developed by Lloyd Lofquist ot Camp Hood, Texas, during World War II.

[7] All tests not directly cited obove were developed by J.P. Guilford and his associates at the University of California. They are described in the five reports by Guilford *et al.* listed in the *References*.

A special motivation instrument was developed as a result of our previously successful experience with a similar device in the earlier communications abilities project. The minimum aspiration level in each of 12 relevant areas was measured by this device which instructed the scientist to indicate the minimum level with which he would be satisfied in each of these abilities and skills felt to be needed in scientific work: reading skills, speaking skills, listening skills, writing skills, quantity of work output, being well liked, administrative advancements, being well known, quantity of reports, theoretical contributions, experimental contributions, and level of original work.

Cattell's new Motivational Analysis Test[8] (MAT, which has also been called the Dynamic Analysis Test) with its 10 scores was also used. The 10 scores were fear, sex, assertion, self-sentiment, wife-sweetheart, sadism, career, super ego, parents-home, narcism-comfort. The strong hope was that at least some of the scores from these different motivational measures would help to account for individual differences in the contributions of scientists.

A special Creative Process Check List was designed from the many descriptions of the creative process, with the hope that valid scores could be attained from checklist responses on one's state of attention and one's feelings before, during, and after solving problems in science. The construction and scoring of this instrument is presented in Appendix B as an illustration of the test development work in this project.

Each scientist was "followed back" to his undergraduate institutions to obtain his undergraduate grade-point average.

A 300-item biographical inventory was constructed from a large pool of rough items already assembled as well as from the interview suggestions, from the biographical results reported at the Utah creativity conferences, and from the biographical results found on 70 scientists in the master's thesis by Robert Ellison (1960). The plan was to try out both empirical and *a priori* keys on this biographical inventory, using both subscores and total scores on each empirical key. This type of inventory was used because in every study on scientists known at that time, selected biographical items had produced promising results. Separate empirical keys were developed for each of the criterion scores 1, 4, 6, 8, 12, and 16. A total of 12 *a priori* biographical scores were used which were judged by their content to measure professional self-confidence, emotional restraint, low sociability, high self-sufficiency, inner directedness, dedication to work, liking to think, intellectual thoroughness, social desirability, self-reported academic level, modal response, and general activity level (see Table 8, Appendix A).

An interesting side study was made possible through the availability of four sets of ratings across the same 17 characteristics presented in the list of self-ratings above. These were the supervisor's ratings of the scientist and of the scientist's job plus the scientist's rating of himself and his job. Six matchings of profiles were accomplished as follows, with the first four being much more meaningful than the last two: (1) the supervisor's ratings of both the scientist and the scientist's job, (2) the scientist's rating of both himself and his job, (3) both the supervisor's rating and the scientist's rating of the scientist, (4) both the supervisor's rating and the scientist's rating of the scientist's job, (5) the supervisor's rating of the scientist and the scientist's rating of the job, and (6) the scientist's rating of himself and the supervisor's rating of the scientist's job. Three different types of profile-matching scores were applied to each of the six matches

[8] Test obtained through personal communication with R.B. Cattell, 1959.

above. One was a total matching, a second was a matching with only the scatter and shape of profiles allowed to vary (with differences in level corrected out), and a third with only the shape allowed to vary (with differences both in level and in scatter corrected out.) Thus, 18 different profile-matching scores were available, which were correlated with the criterion scores 1 - 20 (including the last three control scores of age, total years of work experience, and total months of experience at this research center). This yielded a 38 x 38 correlation table with a section in it which contained 18 x 17 or 306 validity coefficients for the 18 profile-matching scores. Four of these profile-matching scores were selected for inclusion in the final validation study. These four scores had a sizable number of significant correlations with the criteria and also represented the three different types of scoring of the profiles. They were the total profile-matching score on the supervisor's rating of both the scientist and the scientist's job; the shape-only profile-matching score on the same two sets of profiles; the total profile-matching score on both the supervisor's and the scientist's ratings of the scientist; and the scatter-and-shape profile-matching score of both the supervisor's and the scientist's rating of the scientist's job.

In summary, a total of 130 scores were used in the experimental battery to measure the psychological characteristics of the scientists. These 130 scores were derived from the following 16 instruments, six of them developed on this project and most of the others relatively new: Self-Ratings (17 scores), Personality Research Inventory (26 scores), 7 aptitude tests (16 scores), a Minimum Satisfactory Level scale (12 scores), a Motivational Analysis Test (10 scores), a Creative Process Check List (2 scores), Grade-Point Average (1 score), Biographical Information Blank (42 scores), and two rating devices yielding two sets of supervisory ratings of the scientist and the scientist's job plus the scientist's rating of himself and his job (from which ratings the 4 profile matching scores were obtained).

THE SAMPLE

The main sample in the validation study consisted of 107 physical scientists for whom complete or almost complete data were available on all criterion scores and all predictor scores. We faced a dilemma in considering whether to add 30 other scientists who had several scores missing, but for whom a large majority of the 150 scores were available. We finally decided to use the smaller of 107 scientists with practically complete sets of scores instead of expanding to a larger sample of 137 scientists through estimating many missing scores.

Comparison of Turnover with Non-turnover Scientists. During the nearly two years of data collection 28 scientists left the organization. The main sample who remained on the job were compared with the "turnover" sample on the final set of criterion scores (but not on the psychological test scores), including 14 criterion factors, 3 rankings or ratings by peers and immediate supervisors, and 3 control variables of age, total years of work experience, and total months of experience at this research center. The significant differences (all at the .01 level) were that the turnover sample had a much lighter contract monitoring load, were younger, and had less total work experience than the main sample who remained with the research center. Some slight differences (which were not significant at the .05 level) were that the turnover sample had less work experience at this research center, produced slightly higher quality and also slightly more original research reports, had slightly lower organizational status, were slightly less effective paper workers, were judged to be slightly less productive in total work output, and received slightly higher ratings on creativity by laboratory chiefs. (See Table 9, Appendix A.)

In summary, these findings were generally negative since only 3 out of 20 comparisons showed significant differences. The other differences proved to he nonsignificant, but did give

some further suggestion that the turnover sample had some favorable as well as some unfavorable characteristics. The turnover sample wos primarily a yaunger, less experienced group, not as fully established in the research center organization as was the non-turnover group of scientists.

Comparison of the Fully Cooperative with the Other Scientists in this Project. A similar study has been completed on the question of whether the sample of 107 scientists who cooperated fully in this lengthy research project were either representative of or differed in any major respects from the 49 scientists who for various reasons were unable to cooperate completely, althaugh they did cooperate considerably since only a very few predictar scores out af a very large number were lacking on most of these less cooperative scientists. Many of these scientists had also given considerable time and help to this project during the interview study and the criterion study in which we obtained nearly complete criterion data on all of them.

Again the comparisons between groups were made on only the final set of criterian scores, and not on the psychological test scores. Thase who cooperated fully were found (at the .01 level of significance) to be mare effective in completing paper wark than those who did nat cooperate fully. This difference is reasonable and could be expected, since much paper work was required by our project. The cooperators were alsa found (at the .05 level) ta have less work experience at this research center and to have a higher score on professianal society memberships than the less cooperative graup. Slight, though nat significant differences were noted on other criteria as follows. The cooperators had received slightly less recognition for organizational contributions, were rated as more likable as members of the research team, showed slightly more status-seeking characteristics, had slightly less total years of work experience, showed slightly more originality of written work, and were given slightly lawer supervisory ratings on drive and resourcefulness. (See Table 10, Appendix A.)

In general, the caoperating sample was not particularly different from the less-cooperating sample in 17 out of 20 bases of camparison, differing significantly only in effectiveness in completing paper wark, in total work experience at this research center, and in tatal score on professional society memberships. Consequently, on 17 af the criteria it is deemed reasanable ta consider the main sample of scientists to be representative af this non-turnaver populatian af research scientists. If proper allowance ar adjustment is made on the main sample for possible restriction of range effects on the other three criteria, then the main sample could be considered as representative of the non-turnover population of scientists at this research center on all 20 criterian characteristics.

It should be added that there were counterbalancing trends on the criteria for the turnover sample, in comparison with the less cooperative sample, which resulted in the combined sample of those scientists not studied being more similar ta the main sample studied. For example, those who resigned were significantly younger and those who were unable to cooperate fully tended to be slightly older than the main sample. Anather example is that the resignatian sample had significantly less total work experience than the main sample, whereas the less cooperative sample had significantly more total work experience.

COLLECTION AND PROCESSING OF TEST DATA

The criterion data (scores 1 - 20) were collected during the first extended field trip during the initial study. The large battery of test scores were collected by means af four additional short field trips, spaced acrass several months. During each trip, the busy scientists were asked to take tests requiring ane or more hours of their valuable time. Certain tests with time limits had to be scheduled for testing in small groups; whereas the scientists were asked to complete

other tests, such as the biographical inventory, during time that they could find available at work or at home. Two members of the research team were needed on the later field trips to accomplish the complicated field work. The last field trip was designed solely to collect missing data on scientists who had either been away on a trip, absent from work, or too busy to find time for testing during one or more of the previous trips. Overall, the cooperation was excellent, especially considering the many hours of their time that were required during the interviews, the long criterion data collection period, and the four additional field trips for obtaining their scores on a large variety of psychological tests.

Undergraduate grade-point averages were obtained by writing to the college or university and obtaining this average together with a description of the grading system and their method of converting other grading systems to their grading system. These grades for each scientist were then converted to the one most common system found, to yield the grade-point average used in the study.

The intercorrelations among the 150 scores on the sample of 107 scientists were computed on the IBM 709. This correlation table, containing 11,175 different Pearson correlation coefficients, can be viewed as having four main subdivisions: first, a section of 136 different intercorrelations among the 17 criterion scores reproduced as Table 7, Appendix A; second, a section of 8,385 different intercorrelations among the 130 psychological test scores; third, the 444 correlations of the three control scores with all variables; and fourth, the very important validity section showing the 2,210 validity coefficients for the 130 psychological test scores against the 17 criterion scores. In the remaining pages, the writeup will focus on the validity section of the correlation table, since the intercorrelations among the criteria were the main concern in the previous study in the project. All of these validity coefficients are presented in Table 11, Appendix A. The intercorrelation coefficients among the 130 test scores will be important when attempts are made later to form best-weighted combinations of these scores to predict each set of criterion scores.

THE VALIDATION RESULTS

The validity coefficients showed the relation between criteria and test scores collected on present employees with the test scores collected at a later time than the criteria. The collection of predictor test data began approximately nine months after the criterion data were collected. Including the patch-up trip, there were four different data-collection sessions spaced about four months apart. Consequently, this study design entailing the testing-of-present-employees yields "follow-back" validities more than concurrent validities or follow-up (predictive) validities. It should be added, however, that most of the so-called concurrent validity studies really yield "follow-back" validities, if the sound practice is followed of collecting the criterion data prior to the psychological test data. In such cases, though, it is rare to have a time interval of more than a few hours or days between the collection of the criterion data and the test data.

Predictability of the Criteria. The general finding across all 17 criteria was that slightly more than one out of four scores were valid, so that in the validity section of the correlation matrix, there were 568 significant validity coefficients found in the project. These significant validity coefficients ranged from .19 (at the .05 level) to the high .40's. Although the individual coefficients were generally not very high, most of them seemed to be quite meaningful in terms of the particular on-the-job criteria. The prediction task is very difficult where there are so many different criteria of performance on the job, and where there can be some restriction on both criterion and test scores. For most criteria, a large number of individually valid scores can be combined to produce a battery validity with a noticeable increase in validity over the coefficient for the most valid test score. In dealing with these many valid scores, one gets the impression

of being in a situation of combining a large number of items in item analysis work rather than combining only a handful of test scores as is usually done in forming test batteries. As with items, these data need cross validation to estimate the shrinkage that might occur in new samples.

The following list presents the 17 criteria arranged from highest to lowest in terms of their predictability. The criteria with the greatest percentage of significant validities are at the top of the list of criteria, which are presented in rank order. The percentage of the validity coefficients found to be significantly greater than zero for each criterion is placed in the parentheses. The reader should be warned that one biasing factor underlies this list; through item analysis methods, five empirical keys were developed on the Biographical Information Blank for each of the six criteria *marked with an asterisk.*

9. Likableness as a Research Team Member (44%)
5. Scientific and Professional Society Membership (43%)
13. Current Organizational Status (38%)
6.* Judged Work Output (35%)
8.* Supervisory Ratings on Overall Performance (35%)
15. Peer Rankings on Productivity (35%)
1.* Productivity in Written Work (32%)
7. Creativity Rating by Laboratory Chiefs (29%)
17. Supervisory Rating of Creativity (29%)
16.* Supervisory Rating of Drive-Resourcefulness (25%)
4.* Originality of Written Work (20%)
10. Visibility (20%)
11. Recognition for Organizational Contributions (17%)
2. Recent Publications (14%)
14. Contract Monitoring Load (11%)
12.* Status Seeking, "Organizational-Man" Tendencies (08%)
3. Quality (without Originality) of Research Reports (02%)

If all of the 30 empirically-keyed scores on the Biographical Information Blank are omitted from consideration, the criteria rearrange themselves only slightly in terms of their percentage of validity coefficients for the remaining 100 test scores. In fact, the rank-order correlation between the above list and the rearranged list was .95.

Among the less predictable criteria are Recognition for Organizational Contributions, Contract Monitoring Load, and Status-Seeking Tendencies, none of which was the type of criterion we had most directly in mind as we developed and selected psychological test scores designed to predict creativity and productivity as scientists.

It is admitted that the distributions found for several of the initial criterion scores were unusual in shape. One set of criterion scores warrants special comment on this point. The Recent Publications criterion, which measured the number of research reports in a two-year period, was an unusual and unexpected factor found in the criterion analysis, since it was separate from the lifetime total of articles and research reports found in the first criterion score on Productivity in Written Work. Apparently the Recent Publications criterion arose out of unknown complexities in the ebb-and-flow periods of the productivity of scientists. Consequently many scientists, some of whom had a high written productivity index over their life span to that date, were found to have a score of zero on the Recent Publications criterion. This criterion was also much less predictable than the first criterion on Productivity in Written Work.

These zero scores on the Recent Publications criterion also led to complications on two rating criteria of these two-year research reports, namely, Quality (without Originality) of Research Reports and Originality of Written Work. When a scientist had no reports for the two-year period, no ratings were obtained on their research reports; so an estimated score at the middle of the rating scale was used for such scientists. That is, they were assigned a middle rating on the quality and also on the originality of their research reports. These complications of using many estimated scores at the middle of the rating scale probably at least partly account for the low predictability of these two criteria on the ratings of research reports. Since the Originality of Written Work criterion also included in its composite the patent rate and the number of officially accepted suggestions of a scientist, it was more predictable than the criterion of Quality (without Originality) of Research Reports.

Validity of the Psychological Tests. The types of test scores arrange themselves as follows in terms of the percentage of significant validities (at the .05 level of significance) for all their scores against all of the criteria. No attempt has been made in this list to allow for possible restriction-of-range effects in some of these types of test.

Type of Test	Per Cent of Scores Valid
Biographical Information Blank (BIB) (with empirically keyed scores)	47
Biographical Information Blank (BIB) (a priori keyed scores, only)	34
Self Ratings (SR)	33
Grade-Point Average	24
Minimum Satisfactory Level (MSL)	22
Profile Matching[9]	20
Motivational Analysis Test (MAT)	8
Personality Research Inventory (PRI)	8
Creative Process Check List	6
Aptitude Tests	4

The Biographical Information Blank was clearly the best all-round single instrument for predicting the multiple criteria of the contributions of scientists. It was decidedly best considering empirical keys (built on this sample), and still clearly so, using only a *priori* keys, which were based partly on the results from previous studies using similar items. Extremely high validities on the main sample were obtained for the special empirically-keyed scores as expected for these spurious correlations. However, no cross validation was attempted since it was decided that the entire main sample of 107 scientists should be used as a basis for building the empirical keys.[10] Further evidence of the merit of this type of inventory is found in the results for the a *priori* keyed scores, each of which was obtained from only 15 or 20 selected items, with no items used in more than one key. An average of nearly 6 out of 17 of the validities for these a *priori*

[9] In Vernon Carter's unfinished maters's thesis at the University of Utah, approximately 20% of the validity coefficients for his 18 profile-matching scores were significant against the 17 criteria used in the present study. On the basis of his results, four profile-matching scores were selected for use in this validation study. Forty per cent of the validities proved significant, a small percentage of which were spurious.

[10] Using the same type of inventory on larger samples of NASA scientists, we have recently found cross validities in the .50's and high .40's starting from about the same order of magnitude of validity coefficients as found in the present study on the "initial keyed" sample.

keys were significant, which suggests that we are making progress in learning which responses to key as a result of our studies of scientists and their biographical characteristics.

The second best predictive instrument in terms of the number and magnitude of the validity coefficients was the Self-Ratings on 17 scales. In fact, the 12 best rating scales had an average of about 7½ of the 17 criteria for which they had significant validity coefficients.

The Grade-Point average was valid for only 4 of the 17 criteria and just barely valid for 3 of these 4.

The fourth best predictive device was the Minimum Satisfactory Level scales which yielded 12 scores. The 8 best scores were valid for an average of approximately 5 out of the 17 criteria, and an MSL score was the most valid or one of the most valid scores for 9 of the 17 criteria. This device may well be considered the third rather than the fourth best, since these 12 scores were very rapidly obtained and since at least one of them had a higher validity than the Grade-Point Average on every criterion for which the Grade-Point Average was valid.

Except for occasional scores derived from each test the other predictive tests including the Personality Research Inventory, the Motivation Analysis Test, the Creative Process Check List, and the Aptitude tests, had low percentages of significant validity coefficients.

The low percentage of validities on certain tests, especially on the aptitude tests, was puzzling. The main scores for Revision II and the Word Association test had each been valid for 18 and 16, respectively, out of the 27 situational test criteria in the communication abilities project (C.W. Taylor *et al.*, 1958) and the Visual Imagery test scores had consistently yielded sizable validity coefficients in on electronics course.[11] The remaining high-level aptitude tests were selected to measure presumably important characteristics in scientists such as adaptive flexibility, originality, broadly-diffused attention, conceptual foresight, and sensitivity to problems.

A first possibility as to why these high-level aptitude test scores had generally low validities was restriction of range, either through high selection and homogeneity of the sample on these characteristics or through shorter time limits on the tests. Each of these effects which narrow the range of scores may have occurred in some, but certainly not in all, instances. For example, in the communication abilities study, the ratio score of words per idea on the Revision II test had a mean of 21.6 and a standard deviation of 4.1, whereas on the present sample these statistics were 15.2 and 2.3, respectively; in this compactness of expression score the group of scientists performed better and more homogeneously than did the sample in the communication abilities project. The number of words score in the Word Association test, however, had essentially the same mean in both samples and a somewhat larger standard deviation on the sample of scientists, which removes the possibility of the restriction of range explanation for this test. The mean score on the Visual Imagery test was 12.92 for the scientists which was from 2 to 5 points higher than for comparison groups of electronics students (no standard deviations were available for the latter group). Thus, restriction of range was a factor in the Revision II and the Visual Imagery test scores in the present study.

The available evidence also suggests that the scores on the Pertinent Questions and Apparatus tests were restricted in range, due to the use of shorter time limits for the scientists

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[11] Unpublished World War II Army reports by Lloyd Lofquist, Camp Hood, Texas, 1943-1944.

than on other groups tested previously by Guilford. A half length (in both time and items) form of the Pertinent Questions test was used, while a shorter time limit of 7 instead of 10 minutes was used on the full length Apparatus Test. However, there was no evidence of restriction of range on the particular scores on the Match Problems and Consequences tests for which comparative data were available. Nonetheless, the scientists scored higher and showed more variability on the Match Problems test in 5 minutes than did Guilford's sample of air cadets and student officers in 12 minutes (Guilford *et al.*, 1952). For various reasons it is difficult to conclude whether there was much restriction of range on the undergraduate grade-point averages, where the scientists averaged slightly below a "B" with a standard deviation of half a grade point. Of course, it can always be argued that only those who successfully completed college are on the job in scientific laboratories (except for a few rare cases). The reader should be aware that in estimating corrections to overcome restriction of range effects, in most cases it would be expected that validities which were essentially zero would be estimated to remain zero rather than to be significant validities in a sample not showing restriction of range. In other words, many of the zero validities may be truly zero validities regardless of any presence or absence of restriction of range.

A second partial explanation emerges from further comparison with the results in the communication abilities study. Both the Revision II and the Word Association tests may have worked well in that study because they were validated against well controlled, well observed, and systematically scored situational test criteria. In the present study the criterion scores were generally obtained from more naturalistic and less well standardized observations of performance. Perhaps aptitude tests predict more highly structured and less complicated situational test scores better than they predict overall ratings and other types of on-the-job criteria.

The other evidence on the above matters that should be mentioned is that the communication scores of reading, writing, speaking, and listening on the Minimum Satisfactory Level scales were also used in the communication abilities study. The means and standard deviations were essentially comparable across both studies. About half of their validities were significant in the communication abilities study whereas slightly less than one-fifth of the validities were significant in the present study, which generally had less communication features in its multiple criteria.

It is admittedly difficult to draw firm conclusions about these proposed explanations for the numerous low and zero validities, when so many variables are uncontrolled in the comparisons available.

The results on the Creative Process Check List were somewhat disappointing, considering that it was constructed and scored on the basis of the many interesting introspective writings of famous persons about their creative processes. The states-of-attention score had no significant validities and the states-of-feeling score had only two significant validities, and these were quite unexpectedly against the Visibility criterion and the Recognition for Organization Contributions criterion, neither of which was a particularly creative type of criterion. However, the states-of-feeling score was clearly the most valid single score for the Recognition criterion.

CHARACTERISTICS RELATED TO EACH CRITERION

The results will next be presented by listing the characteristics significantly related to each criterion and to each control score in sequence from the highest to the lowest related characteristic. In this description, none of the empirical-keyed biographical scores developed on this sample was included since all such scores correlated spuriously high with the particular criterion for which each one was developed. Biographical scores of the a priori type are included. However,

the profile scores are not included, since they are partly situational scores and would not be available to prospective employees as predictor scores. The instrument from which each score was derived will generally be designated by an abbreviation in parentheses after the score. The abbreviations are SR for Self Ratings, PRI for Personality Research Inventory, MSL for the aspirational self report on Minimum Satisfactory Level, MAT for the Motivation Analysis Test, and BIB for an a priori score on the Biographical Information Blank.

CRITERION 1. PRODUCTIVITY IN WRITTEN WORK

Vor Nr	Predictor		r	Vor Nr	Predictor		r
141	BIB	Liking to think	.43	89	MSL	Level of original work	.28
86	MSL	Quantity of reports	.41	138	BIB	High self-sufficiency	.28
135	BIB	Professional self-confidence	.41	34	SR	Discrimination of value	.27
87	MSL	Theoretical contributions	.38	104	GPA	Grade-point average	.27
37	SR	Creativity	.34	81	MSL	Writing skills	.26
139	BIB	Inner directedness	.34	145	BIB	Modal response	-.26
142	BIB	Intellectual thoroughness	.32	143	BIB	Social desirability	-.25
140	BIB	Dedication to work	.31	47	PRI	Self-sufficiency	.23
21	SR	Drive	.30	79	MSL	Speaking skills	.23
82	MSL	Quantity of work output	.30	26	SR	Desire for facts	.19
28	SR	Desire for discovery	.29	45	SR	Altruism	-.19
33	SR	Independence	.28	48	SR	Gregariousness	-.19

This was the main criterion that showed restriction of range, so its validities would generally be higher for the population of scientists at this center than was found for this sample of the scientists. There was a sizable number of characteristics related to this written productivity factor, most of them being very meaningful in their relationship. It should be recalled from the criterion study that scientists with high scores on this criterion were generally rated below average on cooperation by their supervisors.

CRITERION 2. RECENT PUBLICATIONS

Nr	Predictor		r
43	PRI	Compulsiveness	.28
52	PRI	Belief in rights of individuals	-.27
42	PRI	Tolerance of ambiguity	-.24
41	PRI	Tolerance of frustration	-.19
69	Revision:	Total ideas retained	-.19
135	BIB	Professional self-confidence	.19

This criterion factor seemed to be a separate, short-range measure of publication productivity for a two-year period. It did not particularly relate to overall, written productivity and so was an unusual and unexpected factor. The few characteristics related to it, however, shed some light on its nature. Apparently, persons with these characteristics felt compelled to write their reports or they would have found themselves frustrated in a more complicated, ambiguous situation which they could not readily tolerate.

CRITERION 3. QUALITY (WITHOUT ORIGINALITY) OF RESEARCH REPORTS

Nr	Predictor		r
55	PRI	Status aspiration	-.21
95	MAT	Self-sentiment	.20
143	BIB	Sociol desirobility	.20

The positive validity for the social desirability score was atypical for this study, since every other time that it is valid for a criterion, its validity is negative. This criterion was the least predictable criterion in the study, with only three out of 96 scores correlating with it significantly (at the .05 level). As stated earlier, one reason why this criterion was not very predictable was that a sizable number of scientists during the two-year period had zero publications to be judged on quality. Consequently, they were given an estimated quality score at the mean, which increased the difficulty of predicting the scores on this criterion.

CRITERION 4. ORIGINALITY OF WRITTEN WORK

Nr	Predictor		r	Nr	Predictor		r
44	PRI	Impulsiveness	-.25	61	PRI	Progressive (vs. conservative)	.21
139	BIB	Inner directedness	.23	86	MSL	Quantity of reports	.20
24	SR	Cognition	.22	97	MAT	Sadism	.19
37	SR	Creotivity	.22				

The score on aspiration of level of original work was slightly below the level of significance. Even though non-publishers during the two-year period were given estimated scores at the mean on one of the three scores constituting this criterion, enough correlates with meaningful relations emerged to make this one of the most interesting criteria in this study. These valid relations tend to be in expected directions. The non-impulsiveness finding does *not* argue that originality in paper work is related to the spontaneous type of creativity, currently championed by some speculators in creativity.

CRITERION 5. SOCIETY MEMBERSHIP

Nr	Predictor		r	Nr	Predictor		r
37	MSL	Theoretical contributions	.41	82	MSL	Quantity of work output	.27
87	SR	Creativity	.39	139	BIB	Inner directedness	.27
81	MSL	Writing skills	.37	91	Apparatus test: total		.26
36	SR	Intuition	.36	31	SR	Flexibility	.24
89	MSL	Original work	.35	33	SR	Independence	.24
145	BIB	Modal response	-.34	35	SR	Cooperation	.24
29	SR	Information ability	.33	53	PRI	Belief in rights of groups	.23
86	MSL	Quantity of reports	.33	141	BIB	Liking to think	.22
28	SR	Desire for discovery	.33	142	BIB	Intellectuol thoroughness	.21
27	SR	Desire for principles	.31	21	SR	Drive	.20
24	SR	Cognition	.30	60	PRI	Spiritual (vs. natural)	.21
140	BIB	Dedication to work	.29	80	MSL	Listening skills	.20
144	BIB	Self-reported academic level	.28	22	SR	Math ability	.19
32	SR	Persistence	.27	25	SR	Integrity	.20
34	SR	Discrimination of value	.27	135	BIB	Professional self-confidence	.19

This criterion, quite unexpectedly, was one of the two most predictable criteria in this study, with the most valid characteristics pertaining to creative, theoretical written work. The relationships are possibly underestimates because of some restriction of range found earlier in these criterion scores. In this sample of scientists, contrary to earlier suggestions, the valid predictive information indicates that the persons with the more creative characteristics are "belongers" rather than "not-belongers" to professional societies. They are also seekers of new principles; they desire to be efficient listeners; and they have drive, persistence, and dedication to their work.

CRITERION 6. ACTUAL WORK OUTPUT AS JUDGED BY PEERS, SUPERVISORS, AND CHIEFS

Nr	Predictor		r	Nr	Predictor		r
33	SR	Independence	.46	94	MAT	Assertion	-.27
34	SR	Discriminotion of value	.38	36	SR	Intuition	.25
31	SR	Flexibility	.35	83	MSL	Being well liked	.25
24	SR	Cognition	.34	29	SR	Information ability	.25
135	BIB	Professional self-confidence	.32	138	BIB	Self-sufficiency	.23
37	SR	Creativity	.31	136	BIB	Emotional restraint	.23
27	SR	Desire for principles	.28	58	PRI	Masculine vigor	-.20
21	SR	Drive	.27	89	MSL	Original work	.20
23	SR	Resourcefulness	.27	54	PRI	Social confidence	.19
28	SR	Desire for discovery	.27	139	BIB	Inner directedness	.19

Persons scoring high on this criterion are well organized and motivated toward utilizing their own energies and efforts efficiently to be productive in their work.

CRITERION 7. CREATIVITY RATING BY LABORATORY CHIEFS

Nr	Predictor		r	Nr	Predictor		r
141	BIB	Liking to think	.30	37	SR	Creativity	.21
80	MSL	Listening skills	.25	104	GPA	Grade-point average	.21
138	BIB	Self-sufficiency	.25	78	MSL	Reading skills	.20
101	MAT	Narcism (comfort)	.24	140	BIB	Dedication to work	.20
136	BIB	Emotional restraint	.23	24	SR	Cognition	.19
139	BIB	Inner directedness	.23	47	PRI	Self-sufficiency	.19
145	BIB	Modol response	-.23	53	PRI	Belief in rights of groups	.19
21	SR	Drive	.22	94	MAT	Assertion	-.19

Several scores were related to this creativity rating by the higher level supervisor. However, only a few of these, such as liking to think, self-sufficiency, drive, and a self-report on creativity have usually been reported to be associated with creativity.

CRITERION 8. QUALITY OF OVERALL PERFORMANCE AS RATED BY SUPERVISORS

Nr	Predictor		r	Nr	Predictor		r
21	SR	Drive	.36	23	SR	Resourcefulness	.24
34	SR	Discrimination of value	.34	27	SR	Desire for principles	.24
137	BIB	Low sociability	.34	33	SR	Independence	.24
24	SR	Cognition	.33	85	MSL	Being well known	.23
83	MSL	Being well liked	.30	31	SR	Flexibility	.22
87	MSL	Theoretical contributions	.30	142	BIB	Intellectual thoroughness	.22
37	SR	Creativity	.29	143	BIB	Social desirability	-.21
86	MSL	Quantity of reports	.27	144	BIB	Self-reported academic level	.21
139	BIB	Inner directedness	.27	58	PRI	Masculine vigor	-.20
49	PRI	Aggressiveness	-.26	22	SR	Math ability	.19
135	BIB	Professional self-confidence	.26	50	PRI	Attitude to work	-.19
145	BIB	Modal response	-.26	84	MSL	Administrative advancements	.19
36	SR	Intuition	.25				

Many characteristics were related to this criterion on overall quality of performance, though no relationship was very strong. The direction and nature of the drives, aspirations, and attitudes of those high on this criterion are illuminating.

CRITERION 9. LIKABLENESS AS A MEMBER OF THE RESEARCH TEAM

Nr	Predictor		r	Nr	Predictor		r
81	MSL	Writing skills	.46	142	BIB	Intellectual thoroughness	.27
34	SR	Discrimination of value	.41	28	SR	Desire for discovery	.26
37	SR	Creativity	.34	136	BIB	Emotional restraint	.26
138	BIB	Self-sufficiency	.34	141	BIB	Liking to think	.25
31	SR	Flexibility	.33	85	MSL	Being well known	.24
145	BIB	Modal response	-.33	86	MSL	Quantity of reports	.24
24	SR	Cognition	.31	91	Apparatus test: total		.24
36	SR	Intuition	.31	135	BIB	Professional self-confidence	.23
139	BIB	Inner directedness	.31	100	MAT	Parents-home	-.22
27	SR	Desire for principles	.30	42	PRI	Tolerance of ambiguity	.21
101	MAT	Narcism (comfort)	.30	64	Match problems: Nr correct		.20
78	MSL	Reading skills	.30	95	MAT	Self-sentiment	.20
59	PRI	Artistic (vs. practical)	.28	22	SR	Math ability	.19
74	Visual imagery: % marked correct		.28	48	PRI	Gregariousness	-.20
79	MSL	Speaking skills	.27	87	MSL	Theoretical contributions	.19

This criterion was one of the two most predictable criteria in this study. Persons with these characteristics were judged to be valuable members of the research team.

CRITERION 10. VISIBILITY

Nr	Predictor	r	Nr	Predictor	r
135	BIB Professional self-confidence	.30	27	SR Desire for principles	.20
77	Word association: Nr of sets	.23	34	SR Discrimination of value	.20
103	Creative process check list:		37	SR Creativity	.20
	States of feeling	.23	44	PRI Impulsiveness	-.20
31	SR Flexibility	.22			

The above characteristics describe the scientists who were quite visible and well known throughout this research installation.

CRITERION 11. RECOGNITION FOR ORGANIZATIONAL CONTRIBUTIONS

Nr	Predictor	r	Nr	Predictor	r
103	Creative process check list:		73	Visual imagery:	
	States of feeling	.37		wrong attempts + skips	-.20
138	BIB Self-sufficiency	.29	34	SR Discrimination of value	.19
96	MAT Wife, sweetheart	.24	36	SR Intuition	.19
58	PRI Masculine vigor	-.22	82	MSL Quantity of work output	.19
137	BIB Low sociability	.21	135	BIB Professional self-confidence	.19

The most clearly valid characteristic for this criterion was the "states of feeling" score from the Creative Process Check List. It is possible that additional scoring methods will uncover further potential in this check list.

CRITERION 12. STATUS-SEEKING, "ORGANIZATIONAL-MAN" TENDENCIES

Nr	Predictor	r
82	MSL Quantity of work output	-.23
25	SR Integrity	-.21
99	MAT Super ego	.21
47	PRI Self-sufficiency	-.20
95	MAT Self-sentiment	.21
139	BIB Inner directedness	.20

This criterion is a very interesting one because of its valid characteristics as well as the directions of the relations that were found for these few characteristics. In recalling the first study of the contributions of scientists, it was found that promotion rate was the main component in this factor. A *low* number of suggestions officially accepted by the organization and a *low* self-rating on desire for discovery were positively related to promotion rate. These relations in both the criterion and validation studies raise some real puzzles about the type of person who may have a fast promotion rate in a research organization. It will be seen later that some of these characteristics are quite different and, in the cases of self-sufficiency, desire for discovery, and

ospirotion in quontity of work output, ore exoctly opposite to those found for scientists who are the best oll-round contributors. These results suggest thot some stotus-seeking orgonizotionol men, hoving these volues of their own os they function in reseorch orgonizotions, moy occosionally be working ogoinst the truly importont gools of the orgonizotion.

CRITERION 13. CURRENT ORGANIZATIONAL STATUS

Nr	Predictor	r	Nr	Predictor	r
81	MSL Writing skills	.47	29	SR Informotion obility	.23
36	SR Intuition	.41	138	BIB Self-sufficiency	.23
34	SR Discriminotion of value	.39	144	BIB Self-reported ocodemic level	.22
145	BIB Modol response	-.38	86	MSL Quontity of reports	.21
142	RIB Intellectual thoroughness	.37	27	SR Desire for principles	.21
135	BIB Professionol self-confidence	.36	73	Visual imogery: wrong ottempts + skips	-.20
24	SR Cognition	.35	74	Visuol imogery: % correct	.20
37	SR Creotivity	.33	89	MSL Originol work	.20
87	MSL Theoreticol contributions	.32	91	Apporotus test: totol	.20
33	SR Independence	.30	96	MAT Wife, sweetheort	.20
48	PRI Gregoriousness	-.28	78	MSL Reoding	.20
139	BIB Inner directedness	.27	47	PRI Self-sufficiency	.19
31	SR Flexibility	.25	28	SR Desire for discovery	.19
85	MSL Being well known	.25	104	Grode-point overoge	.19
23	SR Resourcefulness	.23			

This wos the third most predictoble criterion in the volidotion study. The most related chorocteristic wos ospirotion in writing skills (MSL) which overlopped 22% of the voriotion in the criterion scores. In summory, the person with high stotus knows thot he needs better writing skills, rotes himself os hoving good judgment, is thorough, self-confident, independent, self-sufficient, ond willing to "live olone with his work" much of the time.

CRITERION 14. CONTRACT MONITORING LOAD

Nr	Predictor	r
98	MAT Coreer	.33
46	PRI Tolkotiveness	.23
54	PRI Social conscience	.22
58	PRI Mosculine vigor	-.21
139	RIB Inner directedness	.19
145	BIB Modol response	-.19

In generol, the few volid chorocteristics were meoningful for this criterion, ond their volidities moy be slightly underestimoted becouse of some indicotion of restriction of ronge in the criterion scores. The predominont finding wos thot the coreer score (MAT) wos importont to those with o heovy lood of contrect monitoring, being the only time thot this coreer score wos volid in the study. Likewise the only time thot the tolkotiveness score (PRI) wos volid wos for this criterion. Apporently those who hod accepted or cultivoted heovy monitoring loods felt somewhot of

a social responsibility to do so, and were more talkative and "career-oriented" than other scientists.

Criterion 15. Peer Ranking on Overall Productivity. This was the first of three initial criterion scores retained in addition to the 14 criterion factors or categories, which were each formed by a composite of initial criterion scores. Since these peer rankings were the most heavily weighted part of criterion 6, Actual Work Output, the results highly overlapped those for criterion 6. In fact, these two criteria differed only in two sets of four characteristics which were at the bare level of significance in validity on one criterion and below that level on the other; while 16 characteristics were found to be in common across them. This finding may be reassuring to those who have doubts about using factor criterion scores in place of initially obtained criterion scores, such as peer rankings. The four characteristics barely valid for peer rankings, but slightly below that level for criterion 6, were mathematical ability (SR), undergraduate grade-point average, intellectual thoroughness (BIB), and a high self-reported academic level (BIB). Contrarily, the four characteristics that were barely valid for criterion 6 but slightly below the significance level of validity for this criterion were emotional restraint (BIB), a low score on masculine vigor (PRI), social confidence (PRI), and inner directedness (BIB).

CRITERION 16. SUPERVISORY RATING OF DRIVE-RESOURCEFULNESS

Nr	Predictor		r	Nr	Predictor		r
137	BIB	Low sociability	.35	58	PRI	Masculine vigor	-.22
21	SR	Drive	.32	139	BIB	Inner directedness	.22
33	SR	Independence	.24	27	SR	Desire for principles	.21
143	BIB	Social desirability	-.24	54	PRI	Social conscience	.21
49	PRI	Agressiveness	-.23	23	SR	Resourcefulness	.20
37	SR	Creativity	.22	34	SR	Discrimination of value	.20

This initial criterion was retained separately because of its strong motivational nature. The crucial question was whether motivation, which is often claimed to be so important in job performance, was a predictable criterion. The answer was affirmative with the very interesting finding that many of the valid characteristics were motivational in nature. The type of motivation that is effective in this scientific work is apparently more of a quiet, independent, task-focused power, not an outwardly socially persuasive or socially aggressive power, not a masculine, physically-vigorous power. It is very interesting that both the criterion ratings on drive and on resourcefulness together with several predictor scores that were highly motivational in nature all clustered together, though their interrelations were not high, nor were their validities very high against any criterion in this project. Although the aspiration scores generally showed good results for other criteria, all of them were missing from this cluster and had no noticeable validity in predicting supervisory ratings of motivation.

These findings clarify somewhat the entire motivational problem. First, motivational scores tend to cluster somewhat loosely in two or more clusters. Secondly, motivation is either a minor contributor (not one of the major contributors) to effective performance on the job or else motivation is currently being measured at a very low level of efficiency.

CRITERION 17. SUPERVISORY RATING OF CREATIVITY

Nr	Predictor		r	Nr	Predictor		r
137	BIB	Low sociability	.32	144	BIB	Self-reported academic level	.24
87	MSL	Theoretical contributions	.31	145	BIB	Modal response	-.24
83	MSL	Being well liked	.29	34	SR	Discrimination of value	.23
49	PRI	Aggressiveness	-.28	37	SR	Creativity	.23
138	BIB	Self-sufficiency	.25	135	BIB	Professional self-confidence	.23
86	MSL	Quantity of reports	.26	142	BIB	Intellectual thoroughness	.22
21	SR	Drive	.25	89	MSL	Original work	.21
139	BIB	Inner directedness	.24	140	BIB	Dedication to work	.19

This initial criterion was singled out because of the special interest in creativity. Several characteristics were related to this criterion rating of creativity, some of which have emerged in other studies. Some of the lowest validities in the above list plus the appearance of other characteristics like self-sufficiency, drive, and low sociability give some reassurance that the supervisory rating is based somewhat on creativity. However, the appearance of other characteristics suggest that some features other than creativity are entering into this criterion rating, a conclusion also supported by the high relation between this creativity rating and other supervisory ratings in the criterion study.

Control Score 18. Age. None of the *a priori* biographical scores and only a few of the other scores were related to age. The *older scientists* made fewer correct responses on Visual Imagery (a difficult visualizing, imaginative task), and had higher aspirations in being well known (MSL), had lower scores both on impulsiveness (PRI) and on aggressiveness (PRI), had higher scores on social know-how (PRI), raised more questions on Pertinent Questions, rated themselves as more resourceful (SR), and retained a higher percentage of the given ideas in the Revision II test. Since age was not highly related to any of these scores and it was also not particularly related to any of the criterion scores, the conclusion in this study is that age is not a very relevant variable, the effect of which does not need to be controlled or somehow partialled out. In other words, very few relations found in the study would be materially altered if the effects of age were either deliberately controlled or statistically partialled out.

Control Score 19. Total Years of Work Experience. Only a few characteristics were related to total work experience. Those with more work experience rated themselves as more resourceful, more skillful in scientific techniques, more discriminating in value, more cognitive, and more independent (all SR). They scored below average in liking to think (BIB) and in the number of correct responses on the Visual Imagery test, and above average in the "states of feeling" score in the Creative Process Check List, in independence (SR), and in aspiration in being well known (MSL). As in the case of the control variable of Age, few relations in this study would be noticeably changed if the effects of total years of work experience were either controlled or partialled out. If this variable is viewed alternately as a predictor variable (which is true whenever total experience is requested in an application blank or interview), it was readily seen in the earlier criterion study that it had essentially zero validity for each of the criterion factors except for a slight negative validity with promotion rate. Consequently there is little evidence from this project that total years of work experience should be used as selection or placement information.

Control Score 20. Total Months of Experience at This Research Center. Only 5 out of 96 scores were related significantly (at the 5% level) to this control variable; so these findings generally do not warrant much attention nor is there great need to control this variable in this study. Those with more experience in this organization rated themselves as more resourceful (SR), had below average scores both on liking to think (BIB) and on tolerance of ambiguity or complexity (PRI), and above average scores on percentage correct on Visual Imagery and on the number of different sets taken on the Word Association test.

Years of Education. The other variable that could be singled out for mention is the years of education. It is usually considered as predictor information to be gathered on application forms and in interviews. It was found in this study to be unrelated to all criterion factors except criterion 1 on the effectiveness in paper work and criterion 5 on scientific and professional society membership for which it is often a prerequisite. In other words, years of education was not a valid score for 12 of the 14 criterion factors and it can be viewed either as a valid predictor of only the other two criterion factors or as a variable whose effects should be cancelled out in these two – and only in these two criteria. As a safety precaution, however, it might be added that slightly stronger relationships and a few more relationships might emerge if a wider range of years of education were present in a sample studied. The same argument might be relevant in case of a wider range of ages in the sample.

CHARACTERISTICS LEADING TO MULTIPLE CONTRIBUTIONS IN SCIENCE

The following characteristics were most valid for predicting across the multiple criteria in this validation study. The number of the 17 criteria for which each predictor score was valid is listed below. For example, a high score on creativity would predict a person to be an above-average contributor in 12 of the 17 criterion scores.

Var Nr	Predictor		Nr Valid
37	SR	Creativity	12
139	BIB	Inner directedness	12
34	SR	Discrimination of value	11
135	BIB	Professional self-confidence	11
24	SR	Cognition	9
27	SR	Desire-for-principles	9
21	SR	Drive	8
138	BIB	Self-sufficiency	8
145	BIB	Modal response (low score)	8
31	SR	Flexibility	7
33	SR	Independence	7
36	SR	Intuition	7
86	MSL	Quantity of reports	7
87	MSL	Theoretical contributions	7
89	MSL	Level of original work	7
142	BIB	Intellectual thoroughness	7
28	SR	Desire for discovery	6
23	SR	Resourcefulness	5
58	PRI	Masculine vigor (low score)	5
144	BIB	Self-reported academic level	5
22	SR	Math ability	4
29	SR	Informative ability	4
47	PRI	Self-sufficiency	4
81	MSL	Writing skills	4
82	MSL	Quantity of work output	4
83	MSL	Being well liked	4
104	Grade-point average		4
137	BIB	Low sociability	4
140	BIB	Dedication to work	4
141	BIB	Liking to think	4
143	BIB	Social desirability (low score)	4
48	PRI	Gregariousness (low score)	3
49	PRI	Aggressiveness (low score)	3
54	PRI	Social conscience	3
78	MSL	Reading skills	3
85	MSL	Being well known	3
91	Apparatus test: total		3
94	MAT Assertion (low score)		3
136	BIB	Emotional restraint	3

In the study plan, it was decided to compare the validities of different ways of measuring personality and motivation. The results, in general, were rather clearcut in both of these comparisons. In measuring personality characteristics the biographical inventory with either of its scoring systems appeared to be better than the self-ratings, which in turn were clearly better than the scores from the usual type of personality inventory. It should also be noted that the differences in validity could not be accounted for in terms of differences in lengths of instruments.

In the motivational area, the self-report on the minimum satisfactory level of achievement, even though very short in time and length, clearly yielded more valid scores than either a new and complex motivational test or the two intellectual measures of motivation which involved the raising of questions and the sensing of problems. A very short activity-level score across four biographical items failed to yield positive results, although to our knowledge no serious attempt has yet been made to develop a set of biographical items designed to yield one or more motivational scores.

One puzzling result was the relative lack of validity of any of the multiple scores from the seven high-level aptitude tests. This finding occurred after we had found many positive results for high-level aptitude tests against criteria of communication abilities (C.W. Taylor *et al.*, 1958). In the previous study, however, the criteria were scores of performance in standardized situational tests, whereas no such criteria were used in the current study even though over 50 criterion scores were collected. The criteria used were ratings, rankings, and other forms of judgments of scientists, scores from official records, and quantity as well as quality judgments of products of scientists. A study is needed to determine whether high-level aptitude scores predict scientific performance in standardized situational tests better than they predicted any of the present criteria. If they do, there would still be the challenging question of the relation of judged performance in standardized situations to judgments about performance on the job, and the question would be particularly difficult if this relation were found to be low.

CHARACTERISTICS LEADING TO CREATIVE CONTRIBUTIONS

Six criteria (1, 4, 6, 7, 8, 17) were singled out because of some creative feature in them. The characteristics listed below were found to be most frequently related to the six criteria.

Vor Nr	Predictor		Nr Valid
37	SR	Creativity	6
139	BIB	Inner directedness	6
21	SR	Drive	5
24	SR	Cognition	5
135	BIB	Professional self-confidence	4
34	SR	Discrimination of value	4
86	MSL	Quantity of reports	4
87	MSL	Theoretical contributions	4
138	BIB	High self-sufficiency	4
145	BIB	Modal response (low score)	4
33	SR	Independence	3
89	MSL	Level of original work	3
142	BIB	Intellectual thoroughness	3
27	SR	Desire-for-principles	3
83	MSL	Being well liked	3
140	BIB	Dedication to work	3
23	SR	Resourcefulness	2
28	SR	Desire-for-discovery	2
31	SR	Flexibility	2
36	SR	Intuition	2
47	PRI	Self-sufficiency	2
49	PRI	Aggressiveness (low score)	2
58	PRI	Masculine vigor (low score)	2
94	MAT	Assertion (low score)	2
104	Grade-point average		2
136	BIB	Emotional restraint	2
137	BIB	Low sociability	2
141	BIB	Liking to think	2
143	BIB	Social desirability (low score)	2
144	BIB	Self-reported academic level	2

Many of these findings are consistent with the research reported on scientists at the Utah creativity conference series. In fact, a pattern of characteristics of low sociability, liking to think with preference for ideas over things and people, self-sufficiency, independence, intuitiveness, flexibility, resourcefulness, femininity, and dedication to their work with high productivity has emerged as characteristics of the more creative scientists in several different studies (Knapp, 1956; Barron & Roe, 1958)

SUMMARY AND CONCLUSIONS

Studies on samples of Air Force scientists accomplished in a three-year project have been presented in this report.

The first study entailed intensive interviews of nearly 200 scientists which yielded voluminous interview reports containing considerable information of value in all of the other studies in the project.

The turnover sample of scientists was compared with the non-turnover sample and those scientists who cooperated fully on this project were compared with those who for one reason or another were unable to cooperate fully. In both comparisons on criteria of performance on the job, the two pairs of groups were more alike than different, with few significant differences. The main sample of scientists were more effective paper workers than either the turnover or the non-cooperating scientists. The turnover sample was somewhat younger, less experienced, and not as fully established in this organization as the non-turnover group of scientist. The group who did not cooperate fully had more work experience at this research center and had a lower score on professional society membership than the fully cooperative group.

In the criterion study, the multiple contributions of a sample of 166 physical scientists, 52 criterion scores, were analyzed, with the finding that these contributions were largely accounted for in terms of 14 main categories. These were productivity in written work, recent research reports, quality (without originality) of research reports, originality of written work, professional society membership, judgment of actual work output, creativity ratings by higher level supervisors, overall quality ratings by immediate supervisors, likableness as a member of the research team, visibility, recognition for organizational contributions, status-seeking tendencies, current organizational status, and contract monitoring load. Age and work experiences were found to be generally unrelated to the above categories of contributions. Years of education was also found to be unrelated to the scientist's contributions, with the exception that it was somewhat related positively to effectiveness in paper work and to professional society membership.

The validation study was completed on 107 of the above scientists, using 130 predictor scores and 17 criterion scores (one for each of the 14 categories plus peer rankings on overall productivity, supervisory ratings on drive-resourcefulness, and supervisory ratings on creativity).

For every criterion there were several predictors with low to moderate validity. If an independent sample of scientists were available, effectiveness of best combinations of predictors could be tested. The most predictable criteria, in terms of number of valid scores, were likableness as a member of the research team, professional society membership, current organizational status, judged work output, supervisory ratings on overall performance, and peer rankings on overall productivity.

The psychological scores found to be valid for each separate criterion have been described. In addition, 40 characteristics were listed, each of which was related to several of the 17 criteria.

The scores that were valid for the largest number of these criteria were those for creativity, inner directedness, discrimination of value, professional self-confidence, cognition, desire for principles, drive, self-sufficiency, flexibility, independence, intuition, aspiration in quantity of research reports, aspirotion in theoretical contributions, aspiration in high level of original work, and intellectual thoroughness.

The most valid psychological tests were the biographical inventory (both with empirical and with a *priori* keyed scores), self-rotings, and a motivational device designed to measure minimum satisfactory level of aspiration. Undergraduate grade-point average correlated significantly with only four of the 17 criteria, with three of these barely at the level of significance.

No attempt has been made in this project to predict the important factor of turnover of scientists. The evidence suggests that the turnover criterion is relatively separate from the other criteria in the study. Further analysis of the avoilable data is needed to determine the characteristics that predict turnover or non-turnover and to see how these characteristics are reloted to those that predict the more successful performances on the job.

This exploratory investigation has identified a wide range of criteria and their possible predictors. Further work is needed to determine:

(a) which of the criteria and predictors provide, in a longitudinal situation, satisfactorily stable and reliable measurement;
(b) how to combine reliable meosures of scientific contributions as criteria of accomplishment;
(c) whether test combinations and empirical keys for self-report predictor instruments can be developed that are valid across several scientific disciplines.

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APPENDIX A
Statistical Tabulations
Tables 2-11

TABLE 2. Names and Sources of Contribution Scores

Source	Nr	Complete Name and Description	M	σ
Supervisor				
	1	Productivity ranking	51.9	17.0
	2	Drive, resourcefulness – sum of 2 ratings on 7-pt scales	8.4	2.6
	3	Math ability, cognition, skill, discr. of value, intuition – sum of 5 ratings on 7-pt scales	20.0	5.1
	4	Integrity – rating on 7-pt scale	4.7	1.1
	5	Desire-for-facts – rating on 7-pt scale	4.3	1.2
	6	Independence, desire-for-principles and for discovery – sum of 3 ratings on 7-pt scales	12.4	3.3
	7	Informative ability – rating on 7-pt scale	4.1	1.2
	8	Flexibility – rating on 7-pt scale	3.9	1.2
	9	Persistence – rating on 7-pt scale	4.4	1.3
	10	Cooperation – rating on 7-pt scale	4.0	1.3
	11	Creation – rating on 7-pt scale	3.7	1.2
Laboratory Chief				
	12	50% retention – nomination for retention with 50% reduction in staff	.5	.5
	13	Productivity – checklist rating on Thurstone-type scale	33.4	15.3
	14	Creativity – checklist rating on Thurstone-type scale	30.0	14.2
	15	Scientist characteristics – checklist rating on Thurstone-type scale	12.9	7.8
Peers				
	16	Average productivity ranking	52.8	15.4
Project Researcher				
	17	Productivity predicted – rating on 5-pt scale	18.4	6.3
	18	Cooperativeness-on-this-project – rating on 5-pt scale	17.4	5.5
	19	How-well-liked – rating on 5-pt scale	18.7	6.7
	20	Noncompliance or alteration of project requests – rating on 5-pt scale	2.2	.9
Official Records				
	21	Number of official awards	.1	.2
Reports & Publications				
	22	Number of research reports for 2-yr period	.9	1.7
Senior Scientists				
	23	Significance of research reports – rating on continuous graphic scale	34.6	5.1
	24	Relevance-timeliness of research reports – rating on continuous graphic scale	40.2	4.0
	25	Organization-lucidity of research reports – rating on continuous graphic scale	39.1	4.6
	26	Originality of research reports – rating on continuous graphic scale	35.2	4.6
	27	Elegance-accuracy-exhaustiveness of research reports – rating on continuous graphic scale	40.0	3.8

(Table continues on next page)

TABLE 2 (*Continued*)

Source	Nr	Complete Nome ond Description	M	σ
Official Records				
	28	Number of patents and invention disclosures per yr of experience	6.6	13.7
	29	Number of contracts monitored	1.8	3.0
	30	Promotion rate	11.4	5.1
	31	Number of suggestions	.3	.3
	32	Pay	8.7	5.9
	33	Primary activity — choice of 5 alternatives of different levels	2.7	1.7
	34	Number supervised	5.2	12.5
	35	Number of assigned activities	3.1	2.2
Questionnaire				
	36	Evaluation of society membership — rating on 3-pt scale	10.6	9.4
Reports & Publications				
	37	Total of journal articles	1.3	2.5
	38	Total of reports and memos	3.7	5.6
Questionnaire				
	39	Total of papers read	1.3	2.8
	40	Papers completed but not yet accepted	.2	.5
	41	Studies completed except for final writeup	4.0	1.3
	42	Self-estimated publications for next 2 years	.9	1.0
	43	Self-evaluation of degree of freedom from factors hindering publishing	2.2	2.2
Peers				
	44	Assignment of new problem — sociometric nominotions of 3 nomes	6.5	2.1
	45	Preferred consultant — sociometric nominatians of 3 names	6.5	2.0
	46	Trustworthiness on technical matters — sociometric nominations of 3 names	7.0	6.5
Peers within Laboratory				
	47	Nomination as outstanding scientist — sociometric nominations of 3 names	2.7	4.2
Peers outside Laboratory				
	48	Nomination as outstanding scientists in research center — sociometric nomination of 3 names	1.2	3.7
Questionnaire				
	49	Age — control variable	35.8	8.0
	50	Years of education (college yrs or equivalent) — control variable	5.9	1.7
	51	Yeors of experience — control voriable	10.9	6.2
	52	Months in this research center — control variable	6.8	4.0

TABLE 3. Intercorrelation Matrix of Criteria of Scientists' Contributions*

Score No.	Name	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52
1.	Prod. rnk., super.	--																																																			
2.	Drive, resource	54	--																																																			
3.	Math, cogn., etc.	55	74	--																																																	
4.	Integrity	32	49	60	--																																																	
5.	Desire for facts	36	64	70	49	--																																															
6.	Indep., discovery	47	77	84	55	75	--																																															
7.	Inform. ability	44	61	70	47	67	73	--																																														
8.	Flexibility	35	60	66	45	59	67	57	--																																													
9.	Persistence	38	60	59	45	44	64	42	53	--																																												
10.	Cooperation	36	51	50	40	35	50	41	50	46	--																																											
11.	Creation	39	60	75	43	65	83	66	58	48	43	--																																										
12.	50% retention	39	28	30	20	26	32	27	20	11	18	23	--																																									
13.	Prod. ckliet	18	16	10	01	20	15	09	07	-05	00	18	29	--																																								
14.	Creat. ckliet	18	13	01	04	05	03	03	-01	-05	02	07	24	72	--																																							
15.	Sci. char. ckliet	14	11	02	08	08	08	03	-01	-09	04	09	28	78	85	--																																						
16.	Prod. rnk., peer	73	44	46	32	28	36	34	25	34	31	30	35	15	21	16	--																																						
17.	Prod. predicted	18	19	28	11	25	28	25	10	15	03	27	36	26	26	22	22	--																																					
18.	Project coop.	-05	-06	-04	-03	-01	03	06	-04	07	05	01	01	-04	-07	-06	-02	00	--																																				
19.	Likability	13	09	19	-01	17	17	21	11	12	03	17	32	27	22	19	19	63	29	--																																			
20.	Noncomply. alter	-08	-23	-20	-16	-14	-21	-13	-09	-15	-17	-21	-16	-05	-07	-06	02	01	16	-07	--																																			
21.	Awards	18	14	11	-01	07	17	09	13	17	14	17	21	09	00	06	10	-04	00	04	-05	--																																
22.	Reports - 2 yr.	22	26	23	18	04	25	23	09	20	13	11	11	03	04	-02	11	01	17	09	00	02	--																														
23.	Signif., reports	11	-10	-14	04	-05	-09	-00	-14	-01	-06	-06	-10	18	25	21	01	02	-09	-05	-01	-03	-06	--																													
24.	Relev., reports	-09	-15	-23	07	-03	-19	-02	-12	-20	-10	-17	-01	16	12	18	-15	01	03	02	00	-10	-01	39	--																												
25.	Organ., reports	11	-09	-12	10	-06	-11	04	-12	-11	-07	-12	09	15	22	22	05	04	00	07	-01	15	02	44	55	--																										
26.	Orig., reports	19	12	09	03	02	06	04	-03	05	04	08	07	14	18	14	15	12	-07	10	-09	-15	12	47	16	05	--																										
27.	Elig., reports	-01	-17	-16	13	-12	-16	-10	-07	-12	00	-21	-04	-07	03	05	-06	-04	-04	-19	11	04	-14	38	40	42	-10	--																									
28.	Patent rate	29	16	15	05	09	12	04	-02	10	-03	12	18	13	17	16	22	-02	12	04	08	06	17	14	03	11	24	-03	--																									
29.	Monitor	32	16	17	05	01	07	16	11	00	01	03	24	15	15	07	18	01	-19	10	-02	-03	29	02	06	09	05	-11	12	--																								
30.	Promotion rate	08	13	17	14	08	11	12	15	10	12	18	10	17	01	08	13	17	02	17	-01	00	00	08	-03	01	07	-04	01	04	--																								
31.	Suggestions	14	06	08	14	10	08	00	00	04	-03	-04	10	-01	10	05	15	11	-03	08	-10	-03	06	14	05	03	24	05	03	01	-15	--																								
32.	Pay	21	05	12	11	-04	02	00	02	15	17	03	21	07	07	06	21	10	01	10	-04	01	02	-05	-04	-01	-02	-06	10	06	00	-09	--																								
33.	Primary activity	16	04	19	20	09	10	09	02	15	09	14	20	06	03	00	19	19	01	16	-10	00	02	-08	-08	-01	-03	-05	02	-01	-02	06	81	--																							
34.	No. supervised	37	10	26	10	10	22	09	13	27	34	16	30	18	16	14	33	10	19	19	-04	33	12	-03	-16	00	-08	02	16	02	00	-01	47	31	--																						
35.	Activities	36	08	19	13	11	17	19	13	21	27	12	19	04	20	07	32	08	17	26	00	05	15	03	-02	04	06	-04	15	20	01	07	34	28	49	--																						
36.	Societies	19	12	13	18	17	23	20	06	12	02	13	20	09	14	14	10	18	01	14	12	-05	14	06	07	08	18	00	24	04	04	02	00	08	15	16	--																					
37.	Articles	18	05	12	08	07	15	17	00	00	-16	14	26	13	15	14	19	29	01	23	-01	-01	12	10	03	13	14	-01	24	13	-03	03	01	10	-08	00	15	--																					
38.	Reports, memos	25	15	25	11	19	25	21	10	11	-02	23	13	12	15	10	08	16	25	22	-07	01	32	06	-08	05	10	-06	26	10	00	02	00	13	14	15	17	38	--																				
39.	Papers read	24	06	16	02	17	17	20	-01	09	00	18	25	25	17	17	12	15	12	22	-06	28	26	-03	00	17	-02	-12	17	15	00	03	04	09	37	26	15	25	31	--																				
40.	Papers completed	14	04	05	-04	09	08	17	-01	04	-16	02	06	03	17	-02	12	22	13	19	01	00	28	04	00	09	08	-07	19	09	-04	02	00	09	09	19	06	23	35	35	--																				
41.	Writeup incompl.	22	14	26	16	24	22	29	03	15	-04	20	06	10	04	03	15	24	21	19	07	-03	15	09	-03	-04	11	01	18	08	05	01	01	09	00	17	26	30	33	17	12	--																			
42.	Pub. estim.	18	00	17	09	05	13	11	-01	06	03	06	05	-05	-04	-05	07	04	23	11	-02	05	31	-04	-06	-01	15	-06	16	01	-07	00	-02	07	04	14	20	25	43	28	32	49	--																		
43.	Pub. hindrances	-01	06	-05	-05	-06	-07	07	-04	00	-08	-03	-06	-08	-09	-11	-07	08	03	02	04	-09	14	02	12	06	06	03	02	-04	-09	01	00	01	-20	-02	01	15	05	03	03	10	07	--																		
44.	New problems	45	47	38	22	27	35	31	33	27	32	27	16	11	09	11	46	20	-11	06	-09	16	17	02	-16	-04	16	-11	05	10	22	12	04	01	07	03	05	04	06	02	10	09	15	-04	--																	
45.	Consultant	45	31	30	20	28	25	18	16	13	19	17	19	12	09	07	46	22	-13	15	-04	07	06	04	-11	-06	12	-08	13	16	06	13	09	08	13	16	01	10	11	11	13	09	08	-10	63	--													
46.	Trustworthy	17	18	20	15	16	15	13	22	15	19	13	-03	02	03	03	16	03	-07	-03	05	00	-03	03	-03	01	03	-01	-01	02	05	-04	-08	01	01	11	10	00	16	07	13	10	04	05	23	20	--											
47.	Lab nomin.	60	31	41	19	26	34	29	18	23	23	32	37	26	28	19	52	26	00	30	-14	25	22	11	-13	09	25	-08	35	29	06	12	09	10	46	35	18	18	19	34	30	09	12	-15	39	47	07	--										
48.	Cntr nomin.	31	19	29	09	14	29	23	01	16	16	30	32	36	35	30	31	28	09	34	-16	25	26	-01	02	15	10	-18	20	21	-01	13	11	09	46	28	13	08	09	46	18	01	01	-21	11	15	02	62	--									
49.	Age	09	01	03	-01	02	-02	-10	-09	18	08	-10	06	02	05	-02	06	-09	05	03	-05	09	03	-16	-11	-11	-18	-08	10	16	-26	02	16	09	27	17	-03	-11	-03	-04	-03	07	-02	-13	-10	01	09	09	17	--						
50.	Educ., yrs.	17	04	12	14	18	15	22	-04	08	-08	11	15	14	22	19	10	11	17	13	-09	03	12	04	12	10	-04	-01	16	12	01	02	-02	14	10	18	39	32	35	15	21	35	25	01	01	-01	10	16	21	18	--					
51.	Work, yrs.	14	06	03	00	03	-01	-05	-05	17	09	-07	11	-02	01	-04	17	-11	12	02	-07	11	04	-22	-12	-14	-13	-09	13	13	-28	02	22	13	29	18	-02	-17	-09	-01	-03	04	-05	-14	-04	06	01	14	18	83	11	--	
52.	Months, Cntr	16	06	09	00	-03	-01	-05	02	12	15	00	07	-06	-04	-10	20	-08	05	07	-08	11	05	-16	-11	-07	-03	-16	02	13	-22	04	19	14	23	11	-15	-22	-12	-02	05	-15	-12	-11	-08	03	08	27	28	49	-09	57	--

*Decimal points have been omitted. N = 165 scientists in several laboratories of one research center.

TABLE 4. Unrotated Factor Matrix of Criterio of Scientists' Contributions

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	XVI	XVII	XVIII	XIX	h^2
1. Prod. rnk., super	72	-13	15	13	-29	-12	12	-07	-11	21	-09	09	-07	-04	-06	-08	-01	-10	-04	79
2. Drive, resource.	64	-38	-25	28	-09	11	06	11	04	12	11	-05	05	13	05	-13	10	02	-05	82
3. Math, cogn., etc.	74	-39	-30	16	03	02	04	09	03	07	-05	-09	-01	-09	-03	04	-05	-11	05	87
4. Integrity	46	-26	-19	23	11	16	30	-09	-06	03	-10	-07	-04	04	-10	10	09	12	13	59
5. Desire for facts	58	-27	-30	23	13	18	06	11	09	-07	-09	09	-10	-14	13	-06	-04	-03	09	69
6. Indep., discovery	73	-33	-39	17	16	14	03	16	-06	06	04	-09	-07	-10	08	-07	05	05	-02	94
7. Inform. ability	61	-19	-37	22	14	02	13	15	03	05	-12	10	07	-12	-11	-04	02	-05	03	72
8. Flexibility	46	-44	-33	26	11	10	03	04	-04	-02	-11	10	08	05	06	-17	-09	-06	-05	69
9. Persistence	53	-41	-20	-04	04	09	16	06	-13	-08	10	-17	-07	17	09	-04	01	04	-18	67
10. Cooperation	41	-51	-02	14	12	05	07	-10	-18	-07	09	02	10	06	-08	-12	10	-05	03	57
11. Creation	62	-30	-32	19	21	07	-08	12	01	09	09	-12	-04	-12	07	04	-06	-17	10	78
12. 50% retention	50	05	19	12	13	-09	-11	11	10	09	-15	05	-11	-03	-08	-09	18	02	-05	46
13. Prod. cklist	37	32	30	31	22	14	-26	-09	24	06	26	12	09	04	04	-08	-08	-13	-08	76
14. Creat. cklist	37	42	36	27	13	21	-14	-16	19	06	23	10	17	13	07	-14	-14	22	02	86
15. Sci. char. cklist	32	37	33	35	24	25	-22	-24	20	13	30	15	10	10	02	-15	-01	05	05	91
16. Prod. rnk., peer	62	-17	18	14	-28	-17	-02	-14	-07	11	-13	06	-14	12	-16	-10	-02	03	12	72
17. Prod. predicted	41	23	-07	24	14	-21	-24	07	23	-22	-25	-13	-18	17	02	06	03	10	-14	69
18. Project coop.	09	13	-09	-30	23	-15	09	07	-12	-21	16	10	-10	18	-15	-20	09	-16	23	50
19. Likability	41	24	06	05	24	-28	-20	24	16	-44	-14	-04	-10	16	-10	-06	-02	02	-03	76
20. Noncomply, alter	-18	10	-04	-08	-03	-14	05	-11	-07	03	-07	15	-15	17	-03	-18	-16	-08	-07	24
21. Awards	21	-10	15	-08	11	07	-18	13	-26	12	04	18	-07	-03	13	08	19	-14	-11	37
22. Reports - 2 yr.	33	14	-11	-12	-06	-16	21	22	-15	15	18	-06	28	12	-18	-04	11	13	-07	52
23. Signif., reports	02	34	19	35	-09	12	30	23	-21	-13	07	-15	-07	-05	23	09	-07	-19	-08	64
24. Relev., reports	-11	36	16	31	15	22	40	-03	-09	-11	-17	03	09	08	-08	10	09	-10	03	68
25. Organ., reports	04	33	27	29	17	13	32	03	-26	08	-17	10	02	13	-04	24	08	13	-05	63
26. Orig., reports	21	27	04	25	-31	-04	14	-07	-07	-18	15	45	08	-12	07	-13	-05	-10	04	62
27. Eleg., reports	-17	13	11	20	09	17	32	-20	-22	05	-21	16	-22	12	06	13	11	-08	-04	50
28. Patent rate	33	23	09	-10	-15	-06	18	04	-05	20	14	-04	-20	03	08	-11	-13	-10	08	40
29. Monitor	25	06	18	06	-19	-08	11	17	11	14	-03	09	17	-12	-29	05	-14	05	-25	44
30. Promotion rate	10	-07	-10	28	16	-23	-14	-15	-08	-05	15	-06	-08	07	-21	13	-15	-11	-15	39
31. Suggestions	12	08	12	13	-15	04	08	06	-04	-10	-07	-14	-07	-09	09	-07	12	23	10	23
32. Pay	24	-25	40	-27	25	-33	17	-34	30	14	-14	-23	13	14	12	03	14	-08	-03	93
33. Primary activity	29	-18	23	-24	27	-28	17	-25	33	06	-23	-24	09	03	16	17	09	04	08	77
34. No. supervised	46	-14	39	-33	32	-07	-08	-12	-29	05	-04	03	-09	02	07	-13	-02	-03	-11	75
35. Activities	41	-03	26	-17	12	-20	21	-10	-11	-13	-08	09	06	-14	-06	-19	-13	09	-03	51
36. Societies	32	27	-16	-08	07	05	10	-22	-07	10	-06	-11	-13	-09	-16	-14	-08	14	-16	43
37. Articles	29	42	-16	06	-05	-18	04	08	16	23	-10	03	-14	02	10	14	06	04	06	48
38. Reports, memos	42	32	-24	-15	03	-19	16	06	02	04	12	12	02	03	19	09	-10	04	11	53
39. Papers read	40	26	08	-15	18	-15	-07	20	-20	12	-04	16	16	-16	12	04	04	-07	08	52
40. Papers completed	29	31	-07	-16	-08	-20	02	15	-10	-05	-10	10	22	10	20	10	-12	07	07	45
41. Writeup incompl.	37	26	-30	-14	-04	-11	21	-13	18	-10	10	12	-20	-16	-07	07	07	-14	-07	56
42. Pub. estim.	30	30	-30	-29	-09	-22	15	-10	-10	-08	13	14	09	-12	-02	09	20	-05	12	58
43. Pub. hindrances	-08	11	-18	06	-05	-14	23	09	12	04	-06	-02	11	11	06	-11	14	-08	-12	24
44. New problems	44	-23	-07	30	-36	-19	15	-17	-16	-04	13	12	05	09	07	14	18	12	-07	70
45. Consultant	42	-15	11	22	-39	-25	-13	-12	04	-09	-07	19	-05	-02	16	12	05	13	04	62
46. Trustworthy	20	-10	-12	03	-10	05	05	-14	-05	-10	-03	19	16	08	04	08	-24	-04	-07	25
47. Lab nomin.	67	03	33	06	-17	-15	-13	15	-26	05	-02	-04	-07	-11	01	06	-16	02	07	78
48. Cntr nomin.	54	13	36	-06	14	07	-22	27	-19	05	03	-12	06	-09	-12	10	-04	06	06	69
49. Age	19	-18	33	-50	-16	35	13	13	26	-17	09	18	-15	09	-10	09	-05	08	-14	82
50. Educ., yrs.	35	31	-11	-17	12	09	17	-06	11	04	04	16	-12	-08	-11	19	-12	22	06	49
51. Work, yrs.	21	-23	38	-53	-21	33	09	15	22	-16	04	13	-13	11	-13	-05	08	04	-04	86
52. Months, Cntr	15	-26	38	-31	-20	19	-02	25	03	-10	-11	-10	11	13	-14	-03	-10	-12	08	58

TABLE 5. Transformation Matrix in the Criterion Study

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
I	-12	-11	-02	-08	-09	-21	-14	-34	-21	-23	-08	-03	-10	-07	-12
II	33	14	20	18	17	-11	23	-53	11	12	-02	-03	-18	03	-15
III	-14	-14	17	10	-13	20	20	-25	22	29	16	-12	22	09	29
IV	00	-12	25	14	-14	21	21	23	23	-13	-14	11	-22	07	-33
V	-10	-07	12	-29	10	-48	19	28	05	20	20	16	26	-20	-27
VI	-26	-11	28	03	08	-26	30	24	-20	09	06	-23	-27	-09	42
VII	08	20	39	24	07	04	-19	28	-21	-35	-23	-22	17	17	20
VIII	28	21	01	-04	-34	-10	-27	00	27	30	17	-23	-43	17	29
IX	34	-17	-28	-09	-18	00	31	-17	18	-45	-37	-10	35	19	33
X	44	14	-06	-31	10	31	09	-18	10	04	13	-08	18	26	-29
XI	-11	28	-31	24	-11	-24	41	19	-38	-02	08	24	-19	-12	17
XII	07	-15	05	-65	-20	28	25	02	14	-29	20	-17	-34	09	16
XIII	-43	49	02	01	-18	-20	32	19	-32	04	-14	-13	26	26	-17
XIV	11	31	31	-22	-19	-07	19	13	-11	-25	-16	22	10	-28	25
XV	25	-25	-08	21	-28	-28	07	11	-20	-20	34	-44	23	-47	-04
XVI	31	-05	42	-21	-28	-23	-27	-30	-35	37	13	46	19	04	16
XVII	-01	-32	-19	-08	-13	-03	-04	-10	-43	-10	-43	-29	-15	-21	-09
XVIII	02	31	-35	-23	49	-25	15	-08	-07	04	-19	-25	-11	-01	-07
XIX	12	-30	-03	-02	-47	28	14	-05	-11	17	-47	-27	03	-58	-14

Note. — Decimal points have been omitted.

TABLE 6. Criterion and Control Scores Used in the Validation Study

Score description			Subscores comprising each factor score				
Criterion Category	Validity Study Nr	Description	Criterion Study Nr	Name	Category Loading	Beta wt	R
A	1	Productivity in written work	37	Articles	.58	.49	
			38	Reports, memos	.37	.15	.61
			28	Patent rate	.29	.13	
B	2	Recent quantity of research reports	22	Reports – 2 yr	.62	---	.62
C	3	Quality (without originality) of research reports	25	Organ., reports	.70	.44	
			24	Relev., reports	.62	.28	.78
			27	Eleg., reports	.54	.24	
D	4	Originality of written work	26	Orig. reports	.72	.70	
			28	Patent rate	.21	.05	.73
			31	Suggestions	.21	.05	
E	5	Scientific and professional society membership	36	Societies	.53	---	.53
F	6	Actual quantity of work output, as judged by peers, supervisor, and laboratory chief	16	Prod. rnk, peer	.61	.39	
			1	Prod. rnk, super.	.58	.25	.64
			45	Consultant	.39	.08	
G	7	Creativity rating by laboratory chief	15	Sci. char. cklist	.84	.61	
			14	Creat. cklist	.79	.29	.86
H	8	Overall performance (quality ratings by supervisor on 10 scales)	8	Flexibility	.67	↑	
			6	Indep., discovery	.65		
			10	Cooperation	.64	equal	
			2	Drive, resource	.63	weighted	
			9	Persistence	.60	average	
			5	Desire for facts	.54	of all	
			3	Math., cogn., etc.	.54	10 ratings	
			11	Creation	.51		
			7	Inform. ability	.50		
			4	Integrity	.48	↓	
I	9	Likableness as an effective member of the research group	12	50% retention	.51	.42	
			17	Prod. predicted	.40	.13	.56
			19	Likability	.39	.19	
J	10	Visibility of the scientist (well known by person or by name)	48	Cntr nominations	.67	.60	
			47	Lab. nominations	.49	.10	.68
			39	Papers read	.34	.02	
K	11	Recognition for organizational contributions	21	Awards	.54	.43	
			34	Nr supervised	.40	.20	.62
			39	Papers read	.38	.20	
L	12	Status-seeking, "organizational-man" tendencies	30	Promotion rate	.54	---	.54
			32	Pay	.89	.68	

(Table continues on next page)

TABLE 6 (*Continued*)

Score description			Subscores comprising each factor score				
Criterion Category	Validity Study Nr	Description	Criterion Study Nr	Name	Category Loading	Beta wt	R
M	13	Current organizational status	33	Primary activity	.81	.27	.91
			29	Monitor	.59	---	.59
N	14	Contract monitoring load					
single criterion	15	Peer ranking on productivity as a scientist	16	-----	---	---	---
single criterion	16	Supervisory rating of drive-resourcefulness	2	-----	---	---	---
single criterion	17	Supervisory rating of creativity (highly reloted to ratings of independence and desire for discovery)	11	-----	---	---	---
O_1	18	Control score of age[a]	49	Age	.82	---	---
O_2	19	Control scores of work, years[a]	51	Work, yrs	.80	---	---
O_3	20	Control score of months, Center[a]	56	Months, Cntr	.48	---	---

[a] The control scores are neither criteria nor predictors (in this study). They are included merely to understand how they relate to the other variables.

TABLE 7. Intercorrelations, Means, and Standard Deviations of Criterion Scores

Crit Nr	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Mean	SD
1	--																	51.02	7.05
2	08	--																1.01	1.94
3	09	-05	--															49.69	8.26
4	22	13	01	--														21.49	3.88
5	22	07	07	19	--													11.69	9.38
6	24	17	03	37	24	--												49.78	6.71
7	32	14	22	26	18	32	--											16.51	3.34
8	26	28	-03	18	25	53	33	--										69.75	15.61
9	33	06	13	19	27	42	31	41	--									50.73	6.11
10	16	27	04	32	13	41	21	33	42	--								50.14	7.24
11	20	10	02	-05	10	28	11	23	25	48	--							49.18	4.53
12	-05	-01	02	03	06	00	08	11	18	-03	-05	--						11.56	5.10
13	23	11	-08	08	30	38	13	33	55	42	35	04	--					49.37	3.01
14	09	39	08	12	12	22	10	12	19	25	12	05	25	--				1.85	3.37
15	26	14	00	34	20	94	29	49	40	39	24	00	38	14	--			52.58	15.71
16	16	33	-01	27	20	52	33	83	30	25	11	04	24	16	45	--		8.25	2.22
17	29	13	-12	18	19	31	33	79	33	36	19	15	30	00	30	55	--	3.69	1.20

Note. — Decimal points have been omitted preceding correlation coefficients.

TABLE 8. Predictor Scores Used in the Validation Study

Test derived from	Nr	Description of score	Mean	SD
Self Reports				
	21	Drive – Self-rating on 7-point scale	4.65	1.08
	22	Math ability – Self-rating on 7-point scale	4.42	1.30
	23	Resourcefulness – Self-rating on 7-point scale	4.74	1.05
	24	Cognition – Self-rating on 7-point scale	4.86	1.02
	25	Integrity – Self-rating on 7-point scale	5.10	1.18
	26	Desire-for-facts – Self-rating on 7-point scale	4.54	1.31
	27	Desire-for-principles – Self-rating on 7-point scale	4.63	1.15
	28	Desire-for-discovery – Self-rating on 7-point scale	4.80	1.28
	29	Informative ability – Self-rating on 7-point scale	4.73	1.27
	30	Skill – Self-rating on 7-point scale	4.52	1.10
	31	Flexibility – Self-rating on 7-point scale	4.58	1.24
	32	Persistence – Self-rating on 7-point scale	4.84	1.27
	33	Independence – Self-rating on 7-point scale	4.80	1.19
	34	Discrimination of value – Self-rating on 7-point scale	4.80	1.01
	35	Cooperation – Self-rating on 7-point scale	4.81	1.27
	36	Intuition – Self-rating on 7-point scale	4.63	1.31
	37	Creativity – Self-rating on 7-point scale	4.23	1.29
Personality Research Inventory (PRI)				
	38	Self-insight – Number right	11.26	2.79
	39	Free-floating anxiety – Number right	6.44	5.05
	40	Self-acceptance – Number right	9.87	3.49
	41	Tolerance of frustration – Number right	9.25	3.58
	42	Tolerance of ambiguity or complexity – Number right	10.64	4.20
	43	Compulsiveness – Number right	10.68	3.27
	44	Impulsiveness – Number right	7.66	3.70
	45	Altruism – Number right	9.48	3.66
	46	Talkativeness – Number right	8.94	5.58
	47	Self-sufficiency – Number right	10.44	4.33
	48	Gregariousness – Number right	5.73	3.12
	49	Aggressiveness – Number right	11.64	6.05
	50	Attitude to work – Number right	14.16	3.50
	51	Foresight – Number right	12.56	3.12
	52	Belief in right of individuals – Number right	12.53	2.33
	53	Belief in rights of groups – Number right	11.27	2.78
	54	Social conscience – Number right	13.07	3.36
	55	Status aspiration – Number right	6.87	2.73
	56	Social know-how – Number right	11.87	2.89
	57	Social status – Number right	15.07	2.74
	58	Masculine vigor – Number right	11.46	3.31
	59	Artistic vs. practical – Number right	9.48	3.42
	60	Spiritual vs. material – Number right	7.35	4.11
	61	Progressive vs. conservative – Number right	11.01	3.34
	62	Liking to think – Number right	14.21	3.25
	63	PRI acquiescence – Number of yes responses	12.13	1.47
Match Problems				
	64	Number of correct responses (a)	7.54	3.26
	65	Number of wrong attempts (b)	4.63	2.58
	66	Per cent correct – a/a + b	58.31	18.94
Consequences				
	67	Total number of acceptable consequences	12.60	4.56
	68	Remoteness score-high consequences	9.36	4.31
Revision II				
	69	Total number of *ideas* retained (a)	23.01	3.88
	70	Total number of *words* used (b)	34.84	6.28
	71	*Ratio* score of words/ideas – b/a	15.22	2.27

(Table continues on next page)

TABLE 8 (*Continued*)

Test derived from	Nr	Description of score	Mean	SD
Visual Imagery				
	72	Total number of correct responses (a)	12.92	4.36
	73	Wrong attempts plus skip-omits (b)	4.13	2.82
	74	Per cent correct of those marked	68.70	22.77
Word Association				
	75	Total number of associated words written	27.50	9.80
	76	Total number of close synonym-type words	13.68	4.12
	77	Number of sets	15.51	3.24
Minimum Satisfaction Scale				
	78	Reading skills – Self-rating on 6-point scale	4.40	0.96
	79	Speaking skills – Self-rating on 6-point scale	4.51	1.02
	80	Listening skills – Self-rating on 6-point scale	4.26	1.01
	81	Writing skills – Self-rating on 6-point scale	4.54	0.98
	82	Quantity of work output – Self-rating on 6-point scale	4.37	1.00
	83	Being well liked – Self-rating on 6-point scale	3.98	0.98
	84	Administrative advancements – Self-rating on 6-point scale	3.72	1.36
	85	Being well known – Self-rating on 6-point scale	3.93	1.05
	86	Quantity of reports – Self-rating on 5-point scale	2.93	1.12
	87	Theoretical contributions – Self-rating on 5-point scale	3.08	1.19
	88	Experimental contributions – Self-rating on 5-point scale	3.31	1.09
	89	Level of original work – Self-rating on 5-point scale	3.70	1.07
Pertinent Question				
	90	Total acceptable questions	13.61	2.21
Apparatus Test				
	91	Total acceptable modifications	10.77	3.73
Motivational Analysis Test				
	92	Fear – Number right	11.60	2.42
	93	Sex – Number right	6.87	2.22
	94	Assertion – Number right	6.67	1.83
	95	Self-sentiment – Number right	40.73	5.69
	96	Wife-sweetheart – Number right	10.36	2.42
	97	Sadism – Number right	7.90	2.70
	98	Career – Number right	12.02	2.31
	99	Super ego – Number right	18.10	3.53
	100	Parents-home – Number right	9.64	3.06
	101	Narcism-comfort – Number right	9.89	2.48
Check List for Scientists				
	102	States of attention – Number right	15.55	5.87
	103	States of feeling – Number right	2.92	1.99
Undergraduate College Record				
	104	Grade-Point Average	5.31	1.03
Biographical Inventory Blank				
	105	Criterion A-empirical key – Developmental history	50.81	4.60
	106	Criterion A-empirical key – Parents and family life	51.12	4.81
	107	Criterion A-empirical key – Academic history	53.91	6.85
	108	Criterion A-empirical key – Adult life and interests	57.43	12.96
	109	Criterion A-empirical key – Total score	71.11	8.20
	110	Criterion F-empirical key – Developmental history	50.36	3.17
	111	Criterion F-empirical key – Parents and family life	50.10	4.24
	112	Criterion F-empiricol key – Academic history	46.98	4.38
	113	Criterion F-empiricol key – Adult life and interest	52.21	10.12
	114	Criterion F-empirical key – Total score	66.44	5.98
	115	Criterion H-empirical key – Developmentol history	50.58	2.92
	116	Criterion H-empirical key – Parents and family life	51.94	4.21
	117	Criterion H-empirical key – Academic history	48.25	4.20

(Table continues on next page)

TABLE 8 (*Continued*)

Test derived from	Nr	Description of score	Mean	SD
Biographical Inventory Blank (*Continued*)				
	118	Criterion H-empirical key – Adult life and interests	49.96	9.34
	119	Criterion H-empirical key – Total score	66.93	5.71
	120	Criterion D-empirical key – Developmental history	48.94	3.30
	121	Criterion D-empirical key – Parents and family life	49.63	4.29
	122	Criterion D-empirical key – Academic history	46.69	2.78
	123	Criterion D-empirical key – Adult life and interests	47.93	9.27
	124	Criterion D-empirical key – Total score	64.44	5.40
	125	Criterion 16-empirical key – Developmental history	50.51	3.49
	126	Criterion 16-empirical key – Parents and family life	49.93	6.73
	127	Criterion 16-empirical key – Academic history	49.89	3.42
	128	Criterion 16-empirical key – Adult life and interests	53.12	7.55
	129	Criterion 16-empirical key – Total score	67.64	5.39
	130	Criterion L-empirical key – Developmental history	50.58	3.13
	131	Criterion L-empirical key – Parents and family life	49.72	4.08
	132	Criterion L-empirical key – Academic history	50.58	4.42
	133	Criterion L-empirical key – Adult life and interests	48.72	8.87
	134	Criterion L-empirical key – Total score	66.44	5.77
	135	Professional self-confidence – A priori key-positive responses only	4.58	2.13
	136	Emotional restraint – A priori key-positive responses only	2.33	1.52
	137	Low sociability – A priori key-positive responses only	4.66	2.40
	138	High self-sufficiency – A priori key-positive responses only	3.78	2.24
	139	Inner directedness – A priori key-positive responses only	3.24	1.61
	140	Dedication to work – A priori key-positive responses only	5.11	1.59
	141	Liking to think – A priori key-positive responses only	4.97	2.40
	142	Intellectual thoroughness – A priori key-positive responses only	2.26	1.51
	143	Social desirability – A priori key-positive responses only	4.19	2.17
	144	Self-reported academic level – Average on pertinent self-rating items	28.01	4.70
	145	Modal response – Number of times average response chosen	6.82	2.94
	146	General activity level	17.09	11.27
Profile Matching				
	147	Supervisor's rating of scientist and his job – Total	7.13	1.86
	148	Supervisor's rating of scientist and his job – Shape	1.08	0.26
	149	Supervisor's rating vs. scientist's rating of scientist – Total	6.42	1.92
	150	Supervisor's rating vs. scientist's rating of his job – Scatter and shape	2.72	0.50

TABLE 9. Comparison of Main Sample with Turnover Sample

Criterion Score Nr	Name	Main Sample (107) M	Main Sample (107) SD	Resignations (28) M	Resignations (28) SD	t*
1	Quantity or productivity in written work	51.02	7.05	49.46	5.04	1.33
2	Recent publications	1.01	1.94	.89	1.26	.40
3	Quality (without originality) of research reports	49.69	8.26	52.43	7.15	-1.76
4	Originality of written work	21.49	3.88	21.04	1.05	1.07
5	Scientific and professional society membership	11.69	9.38	12.28	8.95	-.31
6	Actual work output, as judged by peers, supervisor, and lab chief	49.78	6.71	48.04	6.68	1.22
7	Creativity rating by lab chief	16.51	3.34	17.04	1.76	-1.15
8	Overall performance	69.75	15.61	67.43	15.78	.70
9	Likableness	50.73	6.11	46.86	10.21	.96
10	Visibility	50.14	7.24	49.25	5.86	.68
11	Recognition for organizational contributions	49.18	4.53	50.46	6.76	-.95
12	Status-seeking, "organizational-man" tendencies	11.56	5.10	11.93	4.88	-.36
13	Current organizational status	49.37	3.01	48.32	3.13	1.57
14	Contract monitoring load	1.85	3.37	.57	.82	3.55
15	Peer Ranking	52.58	15.71	49.96	15.12	.89
16	Supervisory rating of drive-resourcefulness	8.25	2.21	7.89	2.27	.77
17	Supervisory rating of creation	3.59	1.20	3.71	.99	.09
18	Control score of age	35.76	7.65	31.57	6.59	2.89
19	Control score of work, years	10.61	5.92	7.96	4.81	2.48
20	Control score of months, Center	6.08	4.04	4.79	3.07	1.87

* In this situation, $t_{05} = 1.98$; $t_{01} = 2.62$.

TABLE 10. Comparison of Main Sample with Those Who Did Not Completely Cooperate

Criterion Score Nr	Name	Main Sample (107) M	Main Sample (107) SD	Less Cooperative (49) M	Less Cooperative (49) SD	t*
1	Quantity or productivity in written work	51.02	7.05	48.80	3.47	2.64
2	Recent publications	1.01	1.94	.71	1.74	.97
3	Quality (without originality) of research reports	49.69	8.26	49.86	4.07	-.17
4	Originality of written work	21.49	3.88	20.92	.96	1.42
5	Scientific and professional society membership	11.69	9.38	8.67	6.99	2.34
6	Actual work output, as judged by peers, supervisor, and lab chief	49.78	6.71	49.61	5.75	.16
7	Creativity rating by lab chief	16.51	3.34	16.14	3.13	.67
8	Overall performance	69.75	15.61	69.39	14.39	.15
9	Likableness	50.73	6.11	49.26	4.98	1.60
10	Visibility	50.14	7.24	49.82	5.29	.31
11	Recognition for organizational contributions	49.18	4.53	51.16	7.46	-1.72
12	Status-seeking, "organizationol-mon" tendencies	11.56	5.10	10.26	4.65	1.57
13	Current organizational status	49.37	3.01	48.94	3.24	.74
14	Contract monitoring load	1.85	3.37	1.61	1.63	.60
15	Peer ranking	52.58	15.71	53.45	15.67	-.32
16	Supervisory rating of drive-resourcefulness	8.25	2.21	8.61	1.98	-1.03
17	Supervisory rating of creation	3.69	1.20	3.53	1.09	.84
18	Control score of age	35.76	7.65	36.59	5.72	-.75
19	Control score of work, years	10.61	5.92	12.12	5.92	-1.48
20	Control score of months, Center	6.08	4.04	7.67	3.84	-2.37

* In this situation, $t_{05} = 1.98$; $t_{01} = 2.62$.

TABLE 11. Validity Coefficients for 17 Criterio

Test Score	Criterion Score																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
21	30	15	-05	-01	20	27	22	36	06	02	03	-05	07	-09	26	32	25
22	16	04	-06	05	19	18	01	19	19	03	09	-03	19	-02	19	02	16
23	02	14	-06	06	18	27	10	24	12	04	00	-07	23	-01	26	20	17
24	12	10	02	22	30	34	19	33	31	14	15	-02	35	07	31	18	22
25	07	-02	09	-09	20	07	03	-03	01	-01	09	-21	05	-13	05	-10	-12
26	19	07	03	-02	16	11	15	14	02	-02	-02	-13	13	13	12	18	04
27	17	06	-08	09	31	28	20	24	30	20	13	-10	21	00	26	21	16
28	29	02	03	14	33	27	18	16	26	06	12	-11	19	-09	26	14	08
29	11	00	01	08	33	25	07	13	18	04	09	-03	23	02	24	02	-01
30	00	11	-05	-03	16	18	11	12	08	-01	03	-06	01	-10	18	15	04
31	04	05	08	10	24	35	06	22	33	22	13	-02	25	13	37	08	10
32	10	10	-07	06	27	13	05	01	10	02	-04	-15	09	-15	13	00	-06
33	28	07	-07	12	24	46	08	24	15	11	15	-10	30	01	46	24	16
34	27	17	-03	15	27	38	13	34	41	20	19	01	39	09	36	20	23
35	-16	-01	14	-04	24	15	08	06	07	05	18	08	11	03	12	01	-06
36	14	04	-01	00	36	25	16	25	31	16	19	03	41	12	20	16	18
37	34	07	-12	22	41	31	21	29	34	20	11	-10	33	-02	30	22	23
38	06	02	06	02	-02	06	02	04	-03	-08	10	09	03	01	05	-04	06
39	08	06	-07	-03	-08	-10	09	05	-06	07	13	03	05	05	-11	03	10
40	01	04	-10	-06	00	-12	-07	-03	00	-11	06	07	01	08	-11	-07	-10
41	-11	-19	04	-06	-01	06	-09	-04	04	-01	-11	-16	-05	01	04	-05	-09
42	05	-24	17	02	-04	03	-03	-12	21	04	11	08	18	07	01	-18	-04
43	15	28	-04	02	16	-06	12	-04	-08	-11	-02	02	-09	03	-04	-03	-05
44	-09	-01	-01	-25	-10	-14	00	-11	-13	-20	05	07	-14	-12	-12	-11	-11
45	-19	-13	00	-18	-08	-05	-07	-01	-12	-08	-01	04	-17	06	-04	-01	01
46	-03	07	10	-04	10	-03	01	-04	03	04	02	11	00	23	-07	-09	04
47	23	00	02	14	07	11	19	-03	16	10	-07	-20	19	-02	09	-05	08
48	-19	-01	04	-09	-18	-13	-12	-09	-20	05	-05	06	-28	-11	-12	-13	-02
49	-10	-09	06	-05	-06	-08	-06	-26	-13	-07	-12	-10	-16	03	-05	-23	-28
50	07	-07	-17	08	06	-05	07	-19	-06	-11	-12	-07	-08	-05	-08	-14	-18
51	-04	03	04	05	07	01	01	-02	05	11	11	-04	09	05	01	-03	-01
52	04	-27	03	-14	-14	06	-11	-06	08	-06	05	-07	11	-05	07	-13	07
53	13	04	11	-17	23	12	19	15	05	03	09	02	12	16	18	11	12
54	-11	12	07	03	15	19	16	10	04	04	-03	05	02	22	18	21	-06
55	-07	12	-21	00	05	-11	-15	-08	-07	00	-03	05	-03	-08	-04	-05	-05
56	-07	-08	14	-06	16	01	-04	-13	-05	03	03	-02	09	12	00	-10	-17
57	-07	03	03	-11	05	12	-10	01	-13	-06	-18	-04	-01	-02	14	06	-10
58	00	-02	-04	-03	-07	-20	-06	-20	-08	-01	-22	06	-13	-21	-12	-22	-01
59	05	-06	02	04	12	11	00	14	28	-01	09	03	19	-06	09	08	07
60	-11	12	17	-04	21	15	10	09	10	04	05	01	15	13	13	05	11
61	01	05	05	21	09	03	03	-05	02	08	00	12	-08	-15	03	00	-11
62	14	04	12	05	04	03	11	-03	15	-01	13	04	00	03	-04	-05	05
63	-02	15	-16	-17	00	-07	-07	-05	-15	-01	03	-11	-10	-09	-01	-05	-03
64	18	03	-12	17	04	16	07	12	20	-08	13	01	11	14	11	05	06
65	-09	05	12	-18	-13	-07	09	03	-05	-02	-12	05	-05	-08	-09	01	08
66	17	-15	18	06	-03	07	02	05	15	-08	10	-10	07	-01	02	00	01
67	-01	06	08	-11	06	-15	-14	-14	14	-06	06	-02	09	14	-15	-16	-12
68	-07	03	06	-05	05	-14	-07	-09	17	-05	05	07	13	08	-14	-14	-02
69	08	-19	10	-08	09	09	01	02	14	-10	06	00	17	-01	12	11	-01
70	15	-13	14	-06	05	-01	00	-05	08	-18	-05	-11	09	-12	04	05	-04
71	03	05	08	00	-10	-04	-08	-06	-07	-12	-16	-08	-10	-12	-01	-05	-03
72	14	01	07	11	08	04	09	18	18	01	06	07	02	-08	03	01	20
73	-08	-11	01	-11	-16	-04	-05	-05	-10	-13	-20	01	-20	-05	-02	02	-04
74	09	11	-03	15	02	10	00	07	28	18	-07	03	20	18	08	05	06
75	-09	03	-01	00	18	01	-11	-01	16	01	05	07	10	-01	03	-10	04
76	03	01	06	16	-01	-06	-05	-03	11	08	13	12	17	01	-06	-07	04

Note.—r_{05} = .19; r_{01} = .25 (N = 107); decimal points omitted.

(Table continues on next page)

TABLE 11 (*Continued*)

Test Score	Criterion Score																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
77	-04	02	17	14	-01	11	00	-03	11	23	01	-04	10	04	07	01	-04
78	13	-11	11	05	14	13	20	14	30	-11	05	-03	20	-08	16	06	09
79	23	12	-08	-01	18	01	12	16	27	10	07	-03	15	00	04	06	12
80	17	-03	09	-04	20	11	25	07	16	00	15	-14	17	-08	13	00	03
81	26	02	-02	04	37	18	18	15	46	16	18	03	47	12	17	07	09
82	30	03	15	00	27	08	08	08	16	12	19	-23	06	-07	10	05	00
83	15	17	-01	-04	17	25	10	30	03	12	12	-09	11	04	25	17	29
84	-05	12	05	-12	01	-04	-03	19	01	11	12	05	04	04	03	12	14
85	13	05	04	-03	29	00	-01	23	24	17	12	-11	25	02	06	09	17
86	41	17	01	20	33	13	10	27	24	17	18	-04	21	-02	11	17	26
87	38	07	-10	11	39	19	13	30	19	17	16	-12	33	-02	15	17	31
88	05	-01	13	04	09	01	-08	-06	-05	11	17	-11	-09	-12	03	-01	-06
89	28	07	07	15	35	20	10	17	29	16	14	-08	20	-05	20	05	21
90	01	01	00	00	-01	02	-01	05	11	08	-01	04	04	-02	04	04	12
91	05	12	03	06	26	13	08	03	24	10	01	01	20	03	09	00	11
92	09	10	14	10	-09	13	18	06	02	06	-03	-01	09	10	13	90	06
93	01	07	01	04	-02	-04	04	-01	-05	-01	-09	-10	-03	-04	-05	03	-08
94	-15	-09	05	-11	-06	-27	-19	-13	-11	-12	-16	01	-12	-05	-21	-13	-14
95	12	-08	20	05	06	07	18	-04	20	10	05	21	12	12	10	-08	07
96	06	-07	-04	02	-01	18	-01	-02	09	14	24	07	20	05	16	-01	-01
97	15	08	-12	19	-04	13	-07	03	-12	-05	02	-02	-09	10	12	07	03
98	18	08	-07	-01	08	13	04	10	09	17	02	-10	04	33	14	15	06
99	-11	01	08	00	-01	07	-01	-06	-01	12	09	21	11	15	03	-07	-03
100	-04	00	08	-16	01	01	-13	08	-22	-10	06	02	-05	10	-05	15	04
101	05	-01	06	08	03	00	24	06	30	01	02	14	12	14	00	-01	11
102	01	12	-06	-06	06	11	09	11	04	01	12	-18	-04	09	11	07	05
103	11	01	-18	-09	13	08	-08	04	12	23	37	-12	17	-02	09	-04	-03
104	27	10	-01	-02	08	16	21	13	13	07	08	-06	19	02	19	04	12
105	64	06	12	17	25	18	27	07	34	11	12	-07	29	25	15	-01	08
106	70	03	15	04	23	10	15	15	24	04	11	15	11	09	11	-02	16
107	66	-01	05	16	20	24	29	13	24	15	28	-02	26	04	26	-05	21
108	80	-03	09	24	27	24	31	24	41	10	13	08	29	05	25	15	26
109	87	00	12	21	29	25	32	21	39	13	19	05	30	10	25	06	24
110	20	19	-01	32	26	63	33	37	26	32	17	-04	23	28	62	38	20
111	20	14	-17	26	30	67	19	41	32	35	21	-06	26	26	66	42	25
112	29	15	-02	19	34	57	26	46	32	32	30	-12	41	09	57	30	36
113	30	17	08	28	25	76	32	46	47	28	29	05	46	25	75	35	28
114	33	21	00	33	35	83	34	55	47	38	32	00	48	29	82	45	35
115	06	16	-04	30	20	44	32	66	19	29	12	08	22	07	37	58	54
116	26	23	-10	09	27	44	30	64	32	18	17	11	24	14	35	48	55
117	21	24	-04	18	27	43	23	64	29	24	26	-01	32	14	39	44	52
118	26	25	08	22	26	51	39	76	46	29	19	13	33	16	45	66	62
119	26	28	-01	24	31	57	40	84	44	32	23	11	36	16	49	69	69
120	22	27	-05	64	28	30	22	12	20	37	14	-07	10	18	31	17	12
121	09	08	-11	60	06	27	14	04	12	17	08	-03	00	14	28	12	02
122	30	10	-02	60	11	23	11	19	18	23	16	05	11	08	22	14	20
123	24	16	03	81	19	32	28	15	31	20	-06	02	17	15	28	23	10
124	25	19	-03	85	19	36	25	15	27	27	04	00	14	18	33	21	12
125	05	17	-07	20	25	38	37	54	19	21	05	10	15	15	31	72	40
126	00	32	-10	08	09	18	01	25	07	09	07	-08	-01	10	13	45	15
127	08	25	04	09	12	40	08	49	18	17	20	-07	27	14	33	63	27
128	16	38	01	29	23	42	29	65	22	20	05	05	25	21	37	83	44
129	13	34	-04	24	23	47	30	66	24	23	12	02	22	22	40	88	43
130	-06	-08	00	07	12	11	08	10	10	-04	-04	67	11	11	07	12	15
131	14	-05	03	01	05	-03	14	10	22	00	-06	60	13	06	-03	02	21
132	-03	-12	06	02	13	-02	18	02	12	-06	02	65	-02	-01	-03	-08	12
133	07	-08	03	01	10	03	11	15	25	-10	-01	76	14	01	01	03	16

(Table continues on next page)

TABLE 11 (*Continued*)

Test Score	Criterion Score																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
134	06	-09	04	03	11	02	15	12	24	-07	-01	83	12	05	00	01	19
135	41	19	-01	14	19	32	16	26	23	30	19	-09	36	16	33	14	23
136	04	03	-09	09	16	23	23	18	26	05	18	-03	10	10	16	18	15
137	16	07	00	17	15	11	17	34	17	16	21	05	14	00	06	35	32
138	28	05	00	16	14	23	25	18	34	17	29	09	23	-01	19	10	25
139	34	-01	-03	23	27	19	23	27	31	13	13	20	27	19	18	22	24
140	31	03	-03	09	29	15	20	09	03	09	04	-05	11	13	10	-03	19
141	43	-10	17	14	22	13	30	11	25	02	12	15	19	-02	12	-07	10
142	32	13	02	03	21	17	10	22	27	10	02	-08	37	08	19	08	22
143	-25	-14	20	-17	-06	-13	-17	-21	-18	-01	-03	-15	-10	-09	-10	-24	-18
144	17	00	09	-05	28	15	06	21	08	10	04	01	22	-02	19	02	24
145	-26	-08	00	-13	-34	-11	-23	-26	-33	-15	-13	-10	-38	-19	-06	-12	-24
146	02	04	12	-03	-12	-07	14	09	01	-09	-03	08	-06	-10	-01	-03	04
147	12	16	-12	05	27	38	30	71	37	31	32	04	30	00	34	53	67
148	15	11	04	-12	16	-08	-02	-07	15	25	36	-09	16	16	-10	-17	-02
149	-04	-10	01	02	-23	-23	-27	-42	-19	-08	-15	-06	-08	-01	-19	-38	-31
150	00	-14	-08	-35	-32	-26	-13	-17	-01	-18	11	-08	-03	-34	-22	-25	-09

APPENDIX B

RATIONALE FOR CONSTRUCTION OF ONE NEW MEASURING INSTRUMENT: THE CREATIVE PROCESS CHECK LIST*

It seems appropriate to present an illustration of problems in the development of new measuring instruments in the important area of scientific talent, especially of the creative type. The illustration chosen was the Creative Process Check List with its two subscores from the states-of-attention check list and the states-of-feeling check list.

Our research in several areas has demonstrated the dependability of instruments of self-report, including check lists, as a means of measuring ability and predicting success. It occurred to us that the introspection of scientists upon their processes of production might yield useful and perhaps unexpected insights if it could be projected objectively for comparative study.

It is well known that many creative people, scientists and others, have recorded their subjective experience in production, making statements exact enough to yield insight into their psychological processes and to allow some comparison of these processes with one another. An example of a body of statements of this kind, made by mathematicians, may be seen in the book *The Psychology of Invention in the Mathematical Field*, by Jacques Hadamard. The interest of first-rate minds in making and comparing records of subjective experience in production is indisputable. The value of such studies can no more be denied than it can be estimated with finality. But the available records have two shortcomings: there is in the first place too little material, and in the second place the records are very diverse in terminology, in mode of presentation, and in scope. Our check list, an instrument by means of which some of the subjective experience of production could be recorded in one linguistic schema, would compel large numbers of subjects to use a common language in reporting in the same fashion on the same matters, and it would enable us to project reported data as a complex of measurable dimensions.

In determining what information to call for, we were guided by Ghiselin's (1958) criterion of creativity: the idea that creativity is an "origination of significant order in the subjective sphere," the shaping for the first time of a part of the accepted "universe of meaning" in terms of which we understand our world and ourselves. We saw as crucial the act of producing such fresh insight, of forming and bringing into focal attention a new configuration. It was observed, moreover, that the best introspective explorations of presumably creative production were much concerned with the character of the producer's attention and the quality of his feeling. We designed the check list to supply information about the states of attention and qualities of feeling which the worker had experienced at three critical moments of production: immediately before, during, and immediately after the formation of a new configuration of insight.

A basic problem in making the check list was semantic. The items of the check list must refer to complex and elusive subjective states by means of words lacking the absolute exactitude of scientifically limited terminology. The problem was to present to the subjects a usable vocabulary, controllably limited in size yet sufficient in scope and precision to supply a language for reporting the phenomena we hoped to use in research.

In building the check list, terms were chosen in an effort, first, to approximate the vocabulary employed by a variety of intelligent, experienced workers in various fields to indicate the

---

* Prepared by Brewster Ghiselin.

CHECK LIST FOR SCIENTISTS: STATES OF ATTENTION AND FEELING DURING PROBLEM SOLVING OR CREATIVE WORK

General instructions: It is often reported that people have varied personal feelings and experiences during different stages of problem solving or creative acts. In order to ideotify some of the possible feelings and experiences which scientists have while engaged in their work, we would like you to check the adjectives in the two lists below which best describe your attention and feeling during creative acts or insightful mental experience.

In List A are some adjectives which might pertain to your attention during such acts. In List B are some other adjectives which might pertain to your feelings during such acts. What is sought is your selection of adjectives that can best serve to report the states of your attention (List A) immediately before, during, and after your action of forming a new insight, or new configuration of any kind; and the state of your feeling (List B) immediately before, during, and after your action of forming a new insight or new configuration.

In completing the following checklists, you are to consider the whole group of adjectives in each list. If an adjective applies to at least some extent at the particular stage of the process under consideration, give it a single check. Otherwise do not mark the adjective at all. In marking each checklist column, indicate what you feel to be true at each stage, even if at times you may seem to be inconsistent in the pattern of adjectives you mark.

You may check any or all of the adjectives if they pertain to your experiences. Begin with List A. When you have finished the task described there please go on to List B. There is no time limit for this exercise--merely think about your experiences and try to mark the adjectives which seem appropriate to you for each given condition within each list.

List A

Check those adjectives in the list below which best describe the various states of ATTENTION which you experience (1) immediately before you grasp a new insight (solution to a problem, etc.) (2) during the moment (s) when you are grasping (shaping) a new insight, etc. and (3) immediately after you have grasped (shaped) a new insight, etc. Make any desired additions to the list in the blank spaces at the bottom. Work down one checklist column at a time.

	(1) Immediately Before	(2) During	(3) Immediately After
focused	( )	( )	( )
diffused	( )	( )	( )
vague	( )	( )	( )
fixed	( )	( )	( )
fluid	( )	( )	( )
narrowed	( )	( )	( )
ranging	( )	( )	( )
inclusive	( )	( )	( )
shifting	( )	( )	( )
vacant	( )	( )	( )
confused	( )	( )	( )
static	( )	( )	( )
expanded	( )	( )	( )
wandering	( )	( )	( )
orderly	( )	( )	( )
scattered	( )	( )	( )
clear	( )	( )	( )
chaotic	( )	( )	( )
contracted	( )	( )	( )
muddled	( )	( )	( )
wavering	( )	( )	( )
intense	( )	( )	( )
variable	( )	( )	( )
faint	( )	( )	( )
jumbled	( )	( )	( )
fluctuating	( )	( )	( )
dazzled	( )	( )	( )
unconfigurated	( )	( )	( )
arrested	( )	( )	( )
configurated	( )	( )	( )
sharp	( )	( )	( )
characterless	( )	( )	( )
dispersed	( )	( )	( )
steady	( )	( )	( )
scanning	( )	( )	( )
searching	( )	( )	( )
_____	( )	( )	( )
_____	( )	( )	( )
_____	( )	( )	( )
_____	( )	( )	( )
_____	( )	( )	( )
_____	( )	( )	( )

List B

Check those adjectives in the list below which best describe the various states of FEELING which you experience (1) immediately before you grasp a new insight (solution to a problem, etc.) (2) during the moment (s) when you are grasping (shaping) a new insight, etc. and (3) immediately after you have grasped (shaped) a new insight, etc. Make any desired additions to the list in the blank spaces at the bottom. Work down one checklist column at a time.

	(1) Immediately Before	(2) During	(3) Immediately After
tense	( )	( )	( )
happy	( )	( )	( )
uneasy	( )	( )	( )
calm	( )	( )	( )
annoyed	( )	( )	( )
excited	( )	( )	( )
serene	( )	( )	( )
sad	( )	( )	( )
cool	( )	( )	( )
inspirited	( )	( )	( )
exalted	( )	( )	( )
frightened	( )	( )	( )
restless	( )	( )	( )
satisfied	( )	( )	( )
feverish	( )	( )	( )
delighted	( )	( )	( )
indifferent	( )	( )	( )
relieved	( )	( )	( )
impatient	( )	( )	( )
depressed	( )	( )	( )
eager	( )	( )	( )
nervous	( )	( )	( )
pleased	( )	( )	( )
anxious	( )	( )	( )
confused	( )	( )	( )
lost	( )	( )	( )
expectant	( )	( )	( )
peaceful	( )	( )	( )
exhausted	( )	( )	( )
dulled	( )	( )	( )
empty	( )	( )	( )
depleted	( )	( )	( )
enriched	( )	( )	( )
pressured	( )	( )	( )
pressed	( )	( )	( )
full	( )	( )	( )
disturbed	( )	( )	( )
troubled	( )	( )	( )
disorganized	( )	( )	( )
_____	( )	( )	( )
_____	( )	( )	( )
_____	( )	( )	( )

note: While you were checking the above lists what sort of act (s) did you have in mind? Problem solving( ), Creative( ), Both( ).

states of attention and feeling they had observed in themselves in the course of their productive activity, and secondly to represent concepts current in psychological investigation of the matter. Terms obviously flattering or denigrative were rejected in favor of neutral equivalents. It was judged best not to afford only one single term for each reference that we anticipated, for the sufficiency of none could be presupposed. The items of the lists include such words as *vague* (used by Einstein and many others), its less common relative *muddled* (used by Whitehead), and still other closely related terms. We excluded the more highly loaded general terms that are common in discussion of creativity, such as "creative," "imaginative," "inspired," the meaning of which is largely in question and the coverage of which is nearly limitless, but we provided a body of terms that we thought could represent phenomena these terms have referred to in responsible use. (See sample form.)

In preparing to score the completed check list, we picked out, in each section of the list, groups of terms indicative of discriminable conditions of consciousness which we judged to be distinctive in the possible modes of behavior, whether productive of configurations or unproductive, at the three specified stages we were investigating. For the purpose of interpreting the first check list on states of attention, we discriminated four aspects of attention that we considered definitive. These we described as "determinancy," or configural firmness and clarity; "breadth," or inclusiveness in envisaging, or range or variety in the activity of envisaging; "flexibility," or freedom of movement among the possible objects of attention or from one state of attention to another; and "indeterminacy," either complete absence of configural forms in the field of consciousness, or, in an imperfect degree of such configural forms, an indefiniteness in their presentation. We next devised a scale of ascending values, expressing what we believed to be the relative fruitfulness at each stage of production, before, during, and after, of the behaviors designated by these terms singly or in combination. A few of the adjectives in the check list functioned as distractors that were never scored. Other adjectives, scored as significant in one of the check list columns for one stage of the creative process, served as distractors in the other two check-list columns for the other two stages of the creative process. Our treatment of the second check list, indicating states of feeling, was similar.

During the tentative development of the scoring system for our scale, we tested its validity against the records of certain subjects in our sample of scientists whom we knew best, particularly those whose performance was least in doubt and whose communication in interviews with us about their experiences in working had been most full, frank, and illuminating. We did not change our scale to conform to these findings, but used them rather to correct our theoretical understanding, insofar as they seemed to cast light upon it. Correction of the scoring system for the scale was made upon the basis of such enlargements of insight as we could stimulate by these and all other means at our disposal. At that stage we felt it was possible for the originator of the test to infer with some accuracy, from the groups of items checked on the list, the characteristic performance of a few of the men in the sample whom he had not interviewed and whose records he had not studied, but who were so well known to another member of the research team that he could estimate the success of the inference.

APPENDIX C

SAMPLE DATA COLLECTION FORMS

Sample Page: Publication and Report Rating Scale
Sample Peer Rating Form
Sample Form: Productivity Ranking
Sociometric Rating Sheet
Sample Page: Personal Data Form
Sample Page: Self-Rating Form
Satisfactory Achievement Scale
Sample Page: Biographical Information Blank

Sample Page: Publication and Report Rating Scale

Instructions: On each scale below, rate the report appearing on the white page by placing an "X" at the point on the line which represents the degree of the characteristics described above each scale. This mark should represent your opinion of the report based on your familiarity with it and the reputation which it has or deserves to have in its field. Be sure to rate on each of the scales below even though you are not intimately familiar with the report.

I. SIGNIFICANCE: Consider the scientific importance of the contribution, its breadth of application, the degree to which it enlarges insight, structures or restructures understanding.

Virtually worthless.	Contributes a little.	A sound contribution.	An extremely important contribution.

II. ACCURACY: Consider precision of the work.

Extremely inaccurate work.	Some errors which decreased its value.	Acceptable, but could have been improved.	Very accurate, precise, and clean-cut.

III. TIMELINESS: Consider how well timed the work was.

The timing was poor.	The timing could have been better.	Rather timely.	Produced when it was needed most.

IV. LUCIDITY: Consider adequacy of communication, clarity, organization, presentation.

So poorly presented that its significance was lost.	Required extra effort to understand it.	The clarity was acceptable but could be improved.	Clear and understandable to those concerned with it.

V. ORIGINALITY: Consider uniqueness, freshness, creativeness, and imagination.

Duplication of other work.	Largely derivative from other work.	Somewhat original.	Highly original.

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You are to rate a man's power to discern value or the absence of value in things, facts, situations, ideas, intellectual relationships, problems, experiments, studies, etc., for scientific purposes of any kind. Consider his ability to discriminate between the pertinent and the irrelevant, the essential and accidental, the fruitful and the barren, his appreciation of what is needed and not needed, his judgment of what is practical or impractical, his sense of what is primary, secondary, and so on, within the focus of his scientific activities.

On the above characteristic, compare each man below with a typical group of scientists you have known during your career. First rate all the men on the rating scale to the left. Then rate each man's job on the scale to the right on the same characteristic.

	Inferior	Somewhat below Average	Average	Somewhat above Average	Good	Outstanding	Truly Exceptional
	Lowest 40%		Middle 20%	Next 15%	Next 15%	Highest 10%	
- name -				- rate the man -			
1. _____	1.						
2. _____	2.						
3. _____	3.						
4. _____	4.						
5. _____	5.						
6. _____	6.						
7. _____	7.						
8. _____	8.						
9. _____	9.						
10. _____	10.						
11. _____	11.						
12. _____	12.						
13. _____	13.						
14. _____	14.						
15. _____	15.						
16. _____	16.						
17. _____	17.						
18. _____	18.						
19. _____	19.						
20. _____	20.						

Non Applicable	Moderate Amount	Considerable Amount	Maximal Amount
-	rate his job -		

Column A

Sample Form: Productivity Ranking

Column B

Most Productive

RANKING OF EMPLOYEES WITH REGARD TO PRODUCTIVITY

Instructions: Listed in Column A is a group of employees in your laboratory whom you are to place in rank order from highest to lowest with regard to productivity on their specific jobs. These men do different kinds of work, to be sure, but you are to rate them with regard to productivity by considering their individual contributions relative to their specific assignments during the period that you have known them.

Think of their total contributions whether tangible (publications, etc.), or intangible (makes useful suggestions, stimulates thinking of others, etc.). We are searching for an estimate by you of the total contribution that the people make to the efforts of the laboratory, hence their overall productivity. BE SURE THAT YOU MAKE YOUR JUDGMENTS SOLELY ON THE BASIS OF PRODUCTIVITY AND CONTRIBUTIONS.

1. Cross out anyone on the list about whom you have no knowledge and therefore cannot rate. Also cross out your own name if it appears on the list.

2. Look at Column A and select the most productive person there. Write his name on the top line of Column B. Then draw a line through his name in Column A.

3. Select the most productive person remaining in Column A, write his name in Column B on the second line, and draw a line through his name in Column A.

4. Continue this process until all of the names have been crossed out in Column A and placed in rank order with regard to productivity in Column B.

5. After you have finished your ranking in Column B, place a check mark at the left of those names whom you feel you have been able to rank with confidence.

Rater _____

Date _____

Least Productive

- For Research Purposes Only -

SOCIOMETRIC RATING SHEET

Instructions: You are to consider the people in your laboratory when you respond to the items listed below. Read each item carefully, select the people who best fit the demands of each item, and write their names on the appropriate lines. Choose anyone you wish from your laboratory only.

ITEM I. If you were in a supervisory position, to whom would you readily give a new problem? Consider the ability to complete the work effectively and ability to organize work well. Although part of this selection will ultimately depend upon technical skills and requirements, try now to think only in terms of the ability to carry out research and complete it well. (Omit technicians.)

A. List no more than three people to whom you would give a new problem.

_____
_____
_____

B. List no more than three people to whom you would most likely not give a new problem.

_____
_____
_____

ITEM II. With whom would you discuss your own research to obtain worthwhile comments and suggestions?

A. List no more than three people with whom you would discuss your research in an effort to get worthwhile ideas.

_____
_____
_____

B. List no more than three people with whom you would not discuss your research in an effort to get worthwhile ideas.

_____
_____
_____

ITEM III. Consider one's ability to report reliable research information.

A. List no more than three people whose word on technical matters you most readily accept.

_____
_____
_____

B. List no more than three people whose word on technical matters you would check before accepting.

_____
_____
_____

Name of Rater _____

What is your best patent? _____

_____

10. BEST RESEARCH REPORT: Please list the publication or other research report that you feel is the best one you have yet produced.

_____

_____

11. BEST ACCOMPLISHMENTS: Please list below the two achievements which you consider your best during your professional career.

_____

_____

12. OUTSTANDING SCIENTISTS AT E R D: Please write below the names of the three scientists in E R D who, on the basis of your own judgment, are the best. Consider their productivity, success, reputation, etc.

_____

_____

_____

Please write below the names of the three best scientists in your laboratory. Consider their total contributions to the laboratory efforts.

_____

_____

_____

This is part of an important experiment. The success of this work depends upon the full cooperation of the sample selected for study. Please return this personal data sheet in the attached envelope (sealed) by Tuesday, March 18, 1958.

Do not discuss this information with anyone except the Research Psychologist.

5. Rate your tendency to uphold the standards of your profession, to report findings honestly, and to weigh evidence objectively, in performing research or in evaluating ideas, men, and performances, no matter how closely you yourself are involved. A man of integrity is disinclined to talk or write with authority before he has won it, and he may be relied on to perform the services he has agreed to render.

RATE YOURSELF: Definitely Below Average ( ); Somewhat Below Average ( ); Average ( ); Somewhat Above Average ( ); Good ( ); Outstanding ( ); Exceptional ( ).

RATE YOUR JOB REQUIREMENTS: Not Applicable ( ); Moderate Amount ( ); Considerable Amount ( ); Maximal Amount ( ).

6. Rate your desire to store up scientific data, to possess the known facts of science, whether in one scientific field or many. Consider the amount and detail of the factual matter you try to amass about any scientific subject on which you focus, and the degree to which you seem to find the gathering of facts a satisfaction, or a virtue, or an end in itself.

RATE YOURSELF: Definitely Below Average ( ); Somewhat Below Average ( ); Average ( ); Somewhat Above Average ( ); Good ( ); Outstanding ( ); Exceptional ( ).

RATE YOUR JOB REQUIREMENTS: Not Applicable ( ); Moderate Amount ( ); Considerable Amount ( ); Maximal Amount ( ).

7. Rate your desire to master the known body of scientific principles and theories. Consider the degree to which you seem eager to grasp any and all such principles, rather than merely to know what you can use on a specific job or in solving some specific problem.

RATE YOURSELF: Definitely Below Average ( ); Somewhat Below Average ( ); Average ( ); Somewhat Above Average ( ); Good ( ); Outstanding ( ); Exceptional ( ).

RATE YOUR JOB REQUIREMENTS: Not Applicable ( ); Moderate Amount ( ); Considerable Amount ( ); Maximal Amount ( ).

8. Rate your desire to add to the body of scientific insight, through discovery or invention. Consider your willingness to tolerate or ignore difficulties, discomforts, or disadvantages and to do hard, exacting work, in order to attain new scientific insight. Think of the intensity of your desire to achieve new insights for their own sake, apart from any specific utility, and of the degree to which you draw major satisfaction in life from searching for such insights.

RATE YOURSELF: Definitely Below Average ( ); Somewhat Below Average ( ); Average ( ); Somewhat Above Average ( ); Good ( ); Outstanding ( ); Exceptional ( ).

RATE YOUR JOB REQUIREMENTS: Not Applicable ( ); Moderate Amount ( ); Considerable Amount ( ); Maximal Amount ( ).

Satisfactory Achievement Scale

On each scale below you are to indicate the minimum achievement that you would be satisfied to attain for the rest of your life. Do not rate your present achievement. Instead place a mark on each scale to show the lowest degree of each achievement with which you would be satisfied. In other words, you would be dissatisfied if you attained any lower degree of that type of achievement, but satisfied if you attained at least as much as you indicate. The scales apply to a typical group of scientists.

	Well Below Average	Slightly Below Average	Average of a Group of Scientists	Slightly Above Average	Considerably Above Average	Far Above Average
1. In all-round reading ability I would be satisfied if I were at least.....	( )	( )	( )	( )	( )	( )
2. In all-round speaking ability I would be satisfied if I were at least.....	( )	( )	( )	( )	( )	( )
3. In all-round listening ability I would be satisfied if I were at least.....	( )	( )	( )	( )	( )	( )
4. In all-round writing ability I would be satisfied if I were at least.....	( )	( )	( )	( )	( )	( )
5. What is the minimum quantity of work output which you would be satisfied to attain during your entire professional career?.....	( )	( )	( )	( )	( )	( )
6. How well liked by your associates and supervisors must you be in order to attain minimal satisfaction?.....	( )	( )	( )	( )	( )	( )
7. What is the minimum degree of administrative (not scientific) advancement which you would be satisfied to attain during your professional career?...	( )	( )	( )	( )	( )	( )
8. In terms of being well known by members of your profession and related sciences, what is the minimum level with which you would be satisfied?...	( )	( )	( )	( )	( )	( )

9. What is the minimum quantity of publications, research reports, etc., with which you would be satisfied during your professional career?.....	I expect to publish rarely. ( )	I expect to publish at least occasionally. ( )	I expect to publish a moderate amount. ( )	I expect to publish rather extensively. ( )	I expect to publish a great deal. ( )
10. What is the minimum contribution to the theoretical development of your specialty in science with which you would be satisfied during your professional career?.....	No theoretical contributions. All experimental or administrative. ( )	Small theoretical contributions. ( )	Moderate theoretical contributions. ( )	Large theoretical contributions. ( )	Very substantial theoretical contributions. ( )
11. What is the minimum contribution to the experimental development of your specialty in science with which you would be satisfied during your professional career?.....	No experimental contributions. All theoretical or administrative. ( )	Small experimental contribution. ( )	Moderate experimental contribution. ( )	Large experimental contribution. ( )	Very substantial experimental contribution. ( )
12. What level of original work will you want to produce at least once in your field in order to satisfy your minimum professional goals?.	Little or no original work. ( )	Noticeable level of original work. ( )	Moderately high level of original work. ( )	High level of original work. ( )	Very high level of original work. ( )

40. Which of the following best describes how you felt about your social skills during your adolescence?
    A. Definitely below average.
    B. Slightly below average.
    C. About average.
    D. Slightly above average.
    E. Definitely above average.

41. During your childhood and adolescence, how old were the people you generally associated with?
    A. Older than myself.
    B. My own age or older.
    C. My own age.
    D. My own age or younger.
    E. Younger than myself.

42. As a youth how often did you confer with your parents or other adults about your occupational choice?
    A. Frequently.
    B. Occasionally.
    C. Seldom.
    D. Never.

43. Between the ages of 12 and 18, who had the most influence on your occupational choice?
    A. Father.
    B. Mother.
    C. An idol.
    D. A friend, or a relative.
    E. None of the above.

44. In senior high school how definite were you about your future occupation?
    A. Definite enough to make every effort toward the specific goal.
    B. Had a good idea, but worked toward a general goal.
    C. Had some ideas, but preferred to remain somewhat undecided.
    D. Had no ideas whatsoever.

45. Altogether, how long did you live away from home up to age 17?
    A. 1 month or less.
    B. 1 to 6 months.
    C. 6 months to 1 year.
    D. 1 to 4 years.
    E. More than 4 years.

46. In general, how much education did your high school friends think was necessary for future success and security?
    A. Some high school.
    B. A high school degree.
    C. A college degree.
    D. A graduate degree.
    E. Don't know.

47. Where did you live during most of your undergraduate years at college?
    A. Home.
    B. College dorm.
    C. Boarding house.
    D. Fraternity house.
    E. None of the above.

48. On the average while in college, how many hours a week did you spend in reading? (Excluding class work.)
    A. None.
    B. 1 to 5.
    C. 6 to 10.
    D. 10 to 15.
    E. Over 15 hours.

49. About how often did you have dates during your last two years (Jr. and Sr. years) in college?
    A. Once or twice a year or less.
    B. From 3 to 11 times a year.
    C. From 1 to 3 times a month.
    D. Once or twice a week.
    E. Three or more times a week.

50. During your undergraduate college work, if several conflicting activities arose, which of the following generally won out?
    A. My social life--dates, movies, etc.
    B. My studies.
    C. Work outside of school.
    D. Athletics.
    E. Other outside activities.

51. When you were about 20 years old, how important was it to you to be well accepted in a social group?
    A. Very important.
    B. Quite important.
    C. Indifferent.
    D. Rather unimportant.
    E. Very unimportant.

Div. 28/4

Aeronautical Systems Division. Personnel Laboratory, Lackland Air Force Base, Texas. EXPLORATIONS IN THE MEASUREMENT AND PREDICTION OF CONTRIBUTIONS OF ONE SAMPLE OF SCIENTISTS, by Calvin W. Taylor, William R. Smith, Brewster Ghiselin, and Robert Ellison. April 1961. vi + 62 p. (Project 7717, Task 17110) (ASD-TR-61-96) (Contract AF 41(657)-158, University of Utah)

Unclassified report

Physical scientists at two Air Force research centers were intensively interviewed concerning the nature of scientific productivity and the characteristics of effective scientists. Based on interview suggestions, data were collected on 52 criteria. These were reduced analytically to 14 factor scores. Following this, several tests and questionnaires were developed for tryout as predictors. Scores from these and previously developed

(over)

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instruments that showed promise were correlated with the factor scores and three of the original criteria. In the sample of 107 scientists, criteria most related to tests and questionnaires (in terms of number of significant correlations) were ratings of likableness as a member of a research team, membership in professional societies, organizational status, rated work output, supervisory ratings on overall performance, and peer ranking on overall productivity. The instruments that had scores correlating with the greatest number of criteria were a biographical data questionnaire, self-ratings, and a questionnaire designed to measure minimum level of aspiration. The outcomes of this investigation were identification of a wide variety of measurable criteria and a number of self-report instruments suitable for future longitudinal followup and validation as a means of identifying kinds of scientific talent needed by the Air Force.

UNCLASSIFIED

Div. 28/4

Aeronautical Systems Division. Personnel Laboratory, Lackland Air Force Base, Texas. EXPLORATIONS IN THE MEASUREMENT AND PREDICTION OF CONTRIBUTIONS OF ONE SAMPLE OF SCIENTISTS, by Calvin W. Taylor, William R. Smith, Brewster Ghiselin, and Robert Ellison. April 1961. vi + 62 p. (Project 7717, Task 17110) (ASD-TR-61-96) (Contract AF 41(657)-158, University of Utah)

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